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# MECHANICAL PROPERTIES, INCLUDING FRACTURE TOUGHNESS AND FATIGUE, CORROSION CHARACTERISTICS AND FATIGUE-CRACK PROPAGATION RATES OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS

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40

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## ABSTRACT

All forty of the ~~2014-T652,~~ 2024-T852, 7075-T7352 and ~~7079-T652~~ hand forgings scheduled for test ~~under this contract~~ have ~~now~~ been received. Chemical analyses have been made and indicate that the samples meet the composition requirements. Most of the tensile, compressive, shear and bearing properties have been determined for all but one of the forgings. Ratios among these properties have been calculated. Modulus, stress-strain and the remaining notch-bend fracture toughness tests will be made soon. The results of axial-stress fatigue tests ~~(R=0.0)~~ of smooth specimens are reported.

The results of the stress-corrosion tests of specimens from the 2, 3 and 5-in. thick hand forgings showed their performance, in general, to be typical or better than typical for these alloys and tempers. Accelerated exfoliation tests of specimens from the 2x8-in. hand forgings displayed very good resistance to exfoliation regardless of alloy.

The results of some tests to determine the effects of notch geometry on the rate of fatigue-crack propagation are presented. Additional tests are being initiated to determine if the uniformity of crack initiation can be improved by using a different notch and crack initiation procedure. Tests are in progress to determine whether it is feasible to change the load during a test to obtain crack-propagation rates at more than one stress level.

TABLE OF CONTENTS

Fourth Technical Management Report

# MECHANICAL PROPERTIES, INCLUDING FRACTURE TOUGHNESS AND FATIGUE, CORROSION CHARACTERISTICS AND FATIGUE-CRACK-PROPAGATION RATES OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS

## I. Introduction.

The design mechanical properties, fracture toughness, corrosion characteristics and fatigue-crack propagation rates are four of the most important factors involved in the selection and efficient design of aircraft structures. Such data are needed for aluminum alloy hand forgings for several reasons: (1) much of the published design data has become obsolete by a change in the basis of specifying minimum properties, from one in which the length, width and thickness were considered, to one where only the thickness is involved; (2) the development of a technique of stress relieval by cold work in compression has resulted in relatively new tempers (TX52) for many of the alloys; and (3) there have been some significant problems with forged parts in recent years that were related to fracture and stress-corrosion characteristics.

Accordingly, the properties of hand forgings of several aluminum alloys currently being used in aircraft structures are being determined under this contract. The tests are intended to provide statistically reliable data for deriving design mechanical properties for MIL-HDBK-5A, including stress-strain and compressive tangent-modulus curves. In

addition, data concerning the fracture toughness, axial-stress fatigue, stress-corrosion, exfoliation and fatigue-crack propagation rates are being obtained.

This Fourth Technical Management Report summarizes the results of tests carried out during the fourth quarter of the contract, and the general status of the program at this time.

## II. Material.

All of the hand forgings scheduled for investigation have now been obtained.

The chemical compositions of the forgings are shown in Table I. The compositions are within the applicable limits specified in Federal Specification QQ-A-367g and The Aluminum Association, "Aluminum Standards and Data", April 1968. The hand forgings were solution heat treated, cold worked and artificially aged in accordance with Military Specification MIL-H-6088D and the recommendations given in The Aluminum Association, "Aluminum Standards and Data, April 1968. The 7075-T7352 hand forgings were stress-relieved and aged to meet the requirements of paragraph 4.10 of Federal Specification QQ-A-367g.

## III. Procedure.

All of the specimens and test procedures were described in the First Technical Management Report, dated May 15, 1968.

## IV. Progress During Quarter.

### A. Mechanical Properties

#### A.1. Tensile, Compressive, Shear and Bearing

Tensile, compressive, shear and bearing tests have been made of 39 forgings, the results of which are summarized in Tables II through V. The ratios showing the relationships among these mechanical properties are summarized in Table VI. The tensile properties of the hand forgings meet the applicable minimum-property requirements shown in Table VII.

Check tests were made in several instances where the values or ratios seemed to be inconsistent with the other data. In such cases where the check test values indicated that a possible error had been made in the testing or in the identification of the original test specimens, the original values have been discarded; where the original values and check test values were in good agreement, the original values have been retained.

Tensile and compressive stress-strain tests, including modulus determinations, will be started soon. The Tuckerman optical instrument to be used in making the strain measurements has been calibrated and meets the ASTM requirements of a Class A extensometer.

#### A.2. Fracture Toughness

To date, notch-bend fracture toughness tests have been made of only two of the twenty hand forgings scheduled for test. The results of the completed tests were reported in the Third Technical Management Report, dated November 15, 1968.

Specimens from all but one hand forging have been fatigue cracked and will be tested soon.

### A.3. Axial-Stress Fatigue

Axial-stress fatigue (R=0.0) tests of specimens from all except the 6x12-in. 7075-T7352 hand forging have been completed. The results of the axial-stress fatigue tests are shown in Table VIII and plotted in Figs. 1 through 4.

## B. Corrosion Characteristics

### B.1. Resistance to Stress-Corrosion Cracking

All of the stress-corrosion test specimens from the 2x8-in., 3x12-in. and 5x20-in. hand forgings were exposed to the 3.5% NaCl alternate immersion test during this quarter.

The remaining 4x16-in. hand forging designated for stress-corrosion testing was received, and specimens were prepared. Specimens are currently being stressed, and tests should begin in late February or early March.

Specimens have been prepared from the 6x24-in. 2024-T852 and 7079-T652 hand forgings; specimens are being prepared from the 7075-T7352 hand forging recently received. Tests will be initiated as soon as specimens from the latter forging are obtained.

Table IX lists the stress-corrosion data, to date, for longitudinal and long-transverse specimens, and Table X shows data for the short-transverse specimens.

Thus far, no longitudinal specimen has failed, which tends to confirm the expected high resistance of all items stressed in this direction.

Long-transverse failures have occurred with 2014-T652 and 7079-T652 specimens stressed at 75% of the yield strength. Microscopic examination of a representative failure in alloy 2014-T652 confirmed that failure was caused by stress-corrosion cracking (Figs. 5 and 6). A similar examination will be made of some 7079-T652 specimens. These failures indicate that some stress-corrosion susceptibility may be expected when 2014-T652 and 7079-T652 forgings are highly stressed in the long-transverse direction, while 2024-T852 and 7075-T7352 forgings should be highly resistant. These data are in good agreement with existing stress-corrosion guidelines for these products.

Failure occurred with short-transverse specimens from each of the four alloys tested. However, with each alloy, failure occurred in only one of three forgings tested, and the various alloys did not fail consistently for any one forging size.

Failure occurred at a stress of 22.5 ksi with specimens from the 3-in. thick 2014-T652 and 5-in. thick 7079-T652 forgings. Microscopic examination of a representative 2014-T652 failure confirmed that failure was due to stress-corrosion cracking (Fig. 7). A similar examination will be made with the 7079-T652 specimens. The performance of these materials was

better than that typically observed with forgings of these alloys, but was within the bounds of existing stress-corrosion data for these materials.

The performance of the 2024-T852 forgings was about as anticipated with only one isolated stress-corrosion failure (Figs. 8 and 9) occurring at 75% of the yield strength with a specimen from the 2-in. thick forging.

The failure of specimens from the 3-in. thick 7075-T7352 forging was totally unexpected, since this alloy and temper have been shown to provide excellent resistance to stress-corrosion cracking. All test failures were therefore examined microscopically and found to be typical intergranular stress-corrosion failures (Figs. 10 and 11). The electrical conductivity of the 3-in. forging, 38.4 to 38.7% IACS, was only slightly above the specified minimum of 38% IACS [MIL-A-22771B (ASG)], and might indicate a marginal aging treatment for this item. Specimens are currently being obtained for retests to confirm the apparently anomalous behavior of this forging.

## B.2. Exfoliation Resistance

Accelerated exfoliation tests of specimens from the 2x8-in. forgings were completed during this quarter.

Specimens from the 2-in. thick forgings displayed very good resistance to exfoliation regardless of alloy, and as shown in Figs. 12 and 13 no significant differences were observed between specimens from different regions (T/10, T/2) relative to the forging thickness.

C. Fatigue Crack Propagation

Preliminary Investigation

The fatigue tests studying the effect of the notch types shown in Figs. 14 and 15 have been completed. Two specimens of each type were tested at maximum gross stresses of 8.2 and 12.3 ksi. As would be expected, crack initiation was more uniform at the higher stress; there was a slight advantage for the sharper notch. At a stress of 8.2 ksi, cracks did not initiate at one side of a mildly notched specimen until two cracks reached lengths of 1/2 in. The cracking was not as eccentric in either of the two specimens having the sharper notch shown in Fig. 15. However, one of these specimens did not crack at all four corners until another crack measured 1/4 in. long.

Although crack initiation is somewhat more uniform for the sharper notch, it is still not as even as desired, particularly for the portions of this program which call for the moist atmospheres or changes in the load as the crack progresses. To determine if another notch would do better, 1/2-in. long elox notches were made in several 7178-T7651 specimens from another program. Crack initiation at 8.2 ksi was improved but was still not uniform enough in all specimens. To improve the uniformity of initiation, the procedure will be changed as follows:

1. A central 0.20-in. long elox notch (Fig. 16) will be made in the test section of the remaining specimens; only the 2014-T652 specimens have been notched.

2. Because crack initiation is more uniform at higher stresses, the cracks will be initiated at net stresses of about 20 ksi. When cracks are visible at all four corners of the notch, the load will be reduced to produce the desired gross stress and the cracks will be propagated to a total "original notch" length of 0.50 in. before test readings are taken. Thus, before crack propagation measurements are made, each crack will be propagated about 0.15 in.; this should put the cracks well beyond any plastic zone produced by the higher initial loading.

The above outlined test procedure is similar to that used for obtaining cracks in fracture toughness specimens.

Consideration will be given to having a few replacement 2014-T652 specimens notched and cracked as described above.

Computer plots of the crack propagation data and rates of crack propagation are shown in Figs. 17 and 18 for the specimens stressed to 8.2 ksi. The long life of specimen MT4 is attributable to the nonuniformity of crack initiation. Consequently, its rate of crack propagation was slower in the earlier stages. Beyond the earlier stages, the type of notch does not appear to have affected the rate of propagation.

Tests are now in progress to determine whether it is feasible to change the load during the test to obtain crack propagation rates at more than one stress level.

## V. Summary.

All of the 40 hand forgings scheduled for test have been received. The chemical compositions of the hand forgings meet the applicable specified limits shown in Table I.

The tensile, compressive, shear and bearing properties determined for 39 of the forgings are shown in Tables II through V. The tensile properties of the hand forgings meet the applicable minimum-property requirements shown in Table VII. Ratios among the properties are shown in Table VI.

The results of the axial-stress fatigue tests completed to date are summarized in Table VIII and plotted in Figs. 1 through 4.

The current status of stress-corrosion tests is shown in Tables IX and X. The performance of the 2014-T652 and 7079-T652 forgings was better than that typical of these materials, but not unexpected. The performance of the 2024-T852 forging was typical of that expected of this alloy and temper. The 2-in. and 5-in. thick 7075-T7352 forgings also performed typically, i.e., were highly resistant, but unexpected failures were encountered with the 3-in. thick 7075-T7352 forging; retests will be made to investigate this anomalous behavior.

Fatigue tests of the 6x24-in. 2014-T652 hand forging at two stress levels indicate that the rates of crack propagation were not affected appreciably by the shape of the notch. However, to improve the uniformity of crack initiation, a different notch and crack initiation procedure will be used for

the other three alloys. Tests of 2014-T652 specimens have been initiated to determine if it is feasible to change loads during a test to obtain crack propagation rates at more than one stress level.

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## VI. Tables and Figures.

TABLE I

CHEMICAL COMPOSITIONS OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS

(F33615-68-C-1385)

| Alloy and Temper | Sample | | Element, Percent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cross-Section Size, in. | Number | Cu | Si | Fe | Mn | Mg | Zn | Cr | Ti |
| 2014-T652 | 2x8 | 341007 | 4.41 | 0.97 | 0.24 | 0.73 | 0.50 | 0.14 | 0.01 | 0.04 |
| | 3x12 | 341008 | 4.47 | 0.98 | 0.22 | 0.70 | 0.69 | 0.11 | 0.01 | 0.04 |
| | 4x8 | 341009 | 4.27 | 0.89 | 0.20 | 0.69 | 0.57 | 0.10 | <0.01 | 0.04 |
| | 4x16 | 341010 | 4.58 | 0.94 | 0.22 | 0.72 | 0.59 | 0.08 | 0.01 | 0.04 |
| | 5x5 | 341011 | 4.27 | 0.89 | 0.20 | 0.69 | 0.57 | 0.10 | <0.01 | 0.04 |
| | 5x10 | 341012 | 4.28 | 0.91 | 0.22 | 0.68 | 0.56 | 0.08 | <0.01 | 0.04 |
| | 5x20 | 341013 | 4.35 | 0.93 | 0.24 | 0.70 | 0.40 | 0.08 | 0.01 | 0.05 |
| | 6x6 | 341014 | 4.27 | 0.89 | 0.20 | 0.69 | 0.57 | 0.10 | <0.01 | 0.04 |
| | 6x12 | 341015 | 4.53 | 0.94 | 0.25 | 0.74 | 0.53 | 0.12 | 0.02 | 0.05 |
| | 6x24 | 341016 | 4.41 | 1.00 | 0.22 | 0.69 | 0.37 | 0.03 | 0.01 | 0.04 |
| | Limits* | | 3.9-5.0 | 0.50-1.2 | 1.0 | 0.40-1.2 | 0.20-0.8 | 0.25 | 0.10 | 0.15 |
| 2024-T852 | 2x8 | 341017 | 4.63 | 0.11 | 0.15 | 0.53 | 1.54 | 0.07 | 0.00 | 0.02 |
| | 3x12 | 341018 | 4.53 | 0.11 | 0.15 | 0.53 | 1.54 | 0.07 | 0.00 | 0.02 |
| | 4x8 | 341019 | 4.51 | 0.13 | 0.19 | 0.57 | 1.72 | 0.24 | 0.02 | 0.03 |
| | 4x16 | 341020 | 4.51 | 0.11 | 0.17 | 0.57 | 1.58 | 0.07 | 0.01 | 0.03 |
| | 5x5 | 341021 | 4.51 | 0.13 | 0.19 | 0.57 | 1.72 | 0.24 | 0.02 | 0.03 |
| | 5x10 | 341022 | 4.48 | 0.10 | 0.12 | 0.52 | 1.52 | 0.05 | 0.01 | 0.03 |
| | 5x20 | 341023 | 4.51 | 0.13 | 0.19 | 0.57 | 1.72 | 0.24 | 0.02 | 0.03 |
| | 6x6 | 341024 | 4.35 | 0.12 | 0.15 | 0.57 | 1.54 | 0.07 | 0.00 | 0.02 |
| | 6x12 | 341025 | 4.48 | 0.10 | 0.12 | 0.52 | 1.52 | 0.05 | 0.01 | 0.03 |
| | 6x24 | 341026 | 4.56 | 0.12 | 0.14 | 0.65 | 1.69 | 0.08 | 0.00 | 0.03 |
| | Limits† | | 3.8-4.9 | 0.50 | 0.50 | 0.30-0.9 | 1.2-1.8 | 0.25 | 0.10 | -- |
| 7075-T7352 | 2x8 | 341027 | 1.60 | 0.10 | 0.13 | 0.02 | 2.50 | 5.65 | 0.19 | 0.03 |
| | 3x12 | 341028 | 1.52 | 0.11 | 0.14 | 0.02 | 2.29 | 5.45 | 0.20 | 0.03 |
| | 4x8 | 341029 | 1.48 | 0.07 | 0.16 | 0.02 | 2.54 | 5.77 | 0.20 | 0.02 |
| | 4x16 | 341030 | 1.52 | 0.12 | 0.16 | 0.02 | 2.53 | 5.62 | 0.19 | 0.04 |
| | 5x5 | 341031 | 1.50 | 0.07 | 0.13 | 0.02 | 2.50 | 5.67 | 0.20 | 0.02 |
| | 5x10 | 341032 | 1.53 | 0.11 | 0.14 | 0.03 | 2.57 | 5.82 | 0.19 | 0.05 |
| | 5x20 | 341033 | 1.48 | 0.12 | 0.16 | 0.02 | 2.60 | 5.72 | 0.20 | 0.04 |
| | 6x6 | 341034 | 1.71 | 0.12 | 0.20 | 0.04 | 2.42 | 5.68 | 0.19 | 0.03 |
| | 6x12 | 341035 | 1.65 | 0.17 | 0.20 | 0.04 | 2.45 | 5.88 | 0.20 | 0.05 |
| | 6x24 | 341036 | 1.40 | 0.10 | 0.14 | 0.02 | 2.60 | 5.68 | 0.19 | 0.03 |
| | Limits* | | 1.2-2.0 | 0.50 | 0.7 | 0.30 | 2.1-2.9 | 5.1-6.1 | 0.18-0.40 | 0.20 |
| 7079-T652 | 2x8 | 341037 | 0.76 | 0.11 | 0.18 | 0.18 | 3.48 | 4.57 | 0.14 | 0.03 |
| | 3x12 | 341038 | 0.76 | 0.11 | 0.18 | 0.18 | 3.48 | 4.57 | 0.14 | 0.03 |
| | 4x8 | 341039 | 0.70 | 0.10 | 0.16 | 0.19 | 3.66 | 4.74 | 0.14 | 0.04 |
| | 4x16 | 341040 | 0.63 | 0.08 | 0.14 | 0.18 | 3.51 | 4.40 | 0.15 | 0.03 |
| | 5x5 | 341041 | 0.70 | 0.08 | 0.16 | 0.17 | 3.38 | 4.42 | 0.14 | 0.03 |
| | 5x10 | 341042 | 0.72 | 0.10 | 0.15 | 0.19 | 3.45 | 4.54 | 0.15 | 0.03 |
| | 5x20 | 341043 | 0.80 | 0.11 | 0.18 | 0.18 | 3.45 | 4.77 | 0.15 | 0.02 |
| | 6x6 | 341044 | 0.65 | 0.09 | 0.17 | 0.17 | 3.30 | 4.46 | 0.14 | 0.04 |
| | 6x12 | 341045 | 0.70 | 0.10 | 0.16 | 0.19 | 3.66 | 4.74 | 0.14 | 0.04 |
| | 6x24 | 341046 | 0.72 | 0.10 | 0.16 | 0.17 | 3.55 | 4.60 | 0.15 | 0.02 |
| | Limits* | | 0.40-0.8 | 0.30 | 0.40 | 0.10-0.30 | 2.9-3.7 | 3.8-4.8 | 0.10-0.25 | 0.10 |

* Federal Specification QQ-A-367g

† The Aluminum Association, "Aluminum Standards and Data", April 1968

$\Big\}$ Maximum unless a range is shown.

Table I

Table II

TABLE II

MECHANICAL PROPERTIES OF STRESS-RELIEVED 2014-T652 ALUMINUM ALLOY HAND FORGINGS
(F33615-68-C-1385)

| SAMPLE | | | TENSILE | | | | COMP. | SHEAR | BEARING‡ EDGEWISE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CROSS-SECTIONAL SIZE, IN. | NUMBER | DIRECTION§ | ULT. STRESS, PSI | YIELD STRESS,* PSI | ELONG. IN 2 IN. OR 4D, % | RED. OF AREA, % | YIELD STRESS,* PSI | ULT. STRESS, PSI | ULT. STRESS, PSI e/D=1.5 | ULT. STRESS, PSI e/D=2.0 | YIELD STRESS,† PSI e/D=1.5 | YIELD STRESS,† PSI e/D=2.0 |
| 2X 8 | 341007 | L | 71 600 | 66 500 | 11.5 | 30 | 69 200 | 44 200 | 101 000 | 122 500 | 87 800 | 101 600 |
| | | LT | 71 700 | 64 900 | 6.0 | 9 | 70 300 | 43 600 | 101 000 | 130 100 | 89 300 | 100 200 |
| | | ST | 66 400 | 61 400 | 9.4 | 34 | 68 700 | --- | --- | --- | --- | --- |
| 3X12 | 341008 | L | 71 800 | 66 200 | 10.5 | 28 | 68 400 | 42 200 | 102 300 | 132 500 | 89 800 | 107 300 |
| | | LT | 71 000 | 65 100 | 7.5 | 12 | 69 800 | 41 800 | 97 100 | 126 900 | 88 600 | 108 200 |
| | | ST | 69 700 | 62 200 | 5.0 | 7 | 69 700 | 41 300 | --- | --- | --- | --- |
| 4X 8 | 341009 | L | 70 300 | 64 200 | 12.5 | 29 | 66 400 | 40 400 | 89 300 | 123 700 | 85 500 | 103 000 |
| | | LT | 69 900 | 63 000 | 7.5 | 12 | 65 100 | 40 600 | 90 700 | 121 700 | 87 200 | 102 100 |
| | | ST | 66 900 | 59 500 | 2.5 | 4 | 69 300 | 39 900 | --- | --- | --- | --- |
| 4X16 | 341010 | L | 69 100 | 62 500 | 11.5 | 26 | 60 200 | 38 700 | 88 600 | 123 900 | 79 300 | 97 400 |
| | | LT | 66 600 | 59 200 | 6.0 | 8 | 61 500 | 38 800 | | 114 900 | | 93 900 |
| | | ST | 65 800 | 57 000 | 6.0 | 6 | 61 900 | 38 900 | --- | --- | --- | --- |
| 5X 5 | 341011 | L | 68 600 | 63 200 | 12.0 | 28 | 65 300 | 41 800 | 88 200 | 117 300 | 85 900 | 101 300 |
| | | LT | 67 500 | 61 200 | 4.0 | 5 | 62 500 | 40 700 | 87 200 | 118 400 | 85 900 | 100 400 |
| | | ST | 65 200 | 58 800 | 2.0 | 4 | 66 500 | 41 200 | --- | --- | --- | --- |
| 5X10 | 341012 | L | 68 800 | 61 600 | 11.5 | 27 | 63 000 | 40 600 | 93 400 | 117 400 | 82 700 | 94 800 |
| | | LT | 67 300 | 60 200 | 5.5 | 9 | 61 700 | 40 300 | 88 700 | 123 400 | 83 600 | 99 000 |
| | | ST | 64 600 | 57 400 | 3.0 | 6 | 65 300 | 39 700 | --- | --- | --- | --- |
| 5X20 | 341013 | L | 68 500 | 60 700 | 11.5 | 24 | 61 200 | 38 800 | 90 100 | 113 500 | 79 000 | 94 300 |
| | | LT | 64 700 | 57 300 | 5.0 | 7 | 63 500 | 38 400 | 86 600 | 117 500 | 79 000 | 94 700 |
| | | ST | 63 900 | 56 100 | 3.7 | 7 | 62 800 | 37 300 | --- | --- | --- | --- |
| 6X 6 | 341014 | L | 67 700 | 62 000 | 12.0 | 31 | 64 000 | 42 400 | 97 400 | 114 200 | 86 700 | 97 500 |
| | | LT | 64 900 | 59 500 | 3.5 | 5 | 60 400 | 40 700 | 89 300 | 121 100 | 83 900 | 101 100 |
| | | ST | 64 200 | 55 900 | 2.8 | 1 | 65 700 | 40 500 | --- | --- | --- | --- |
| 6X12 | 341015 | L | 66 200 | 59 500 | 11.0 | 27 | 60 300 | 40 200 | 91 100 | 120 100 | 81 600 | 96 100 |
| | | LT | 54 200 | 58 400 | 3.5 | 6 | 61 900 | 38 800 | 87 700 | 119 000 | 80 600 | 98 800 |
| | | ST | 63 900 | 55 000 | 3.5 | 2 | 61 900 | 38 700 | --- | --- | --- | --- |
| 6X24 | 341016 | L | 63 000 | 55 900 | 9.5 | 19 | 57 900 | 42 500 | 89 500 | 118 100 | 81 200 | 99 700 |
| | | LT | 66 600 | 57 700 | 6.0 | 6 | 62 400 | 38 800 | 86 300 | 117 900 | 80 000 | 98 900 |
| | | ST | 62 600 | 54 000 | 6.0 | 14 | 59 300 | 39 000 | --- | --- | --- | --- |

* OFFSET EQUALS 0.2 PER CENT
† OFFSET EQUALS 2 PER CENT OF PIN DIAMETER
‡ SPECIMENS AND FIXTURES CLEANED ULTRASONICALLY
§ L, LONGITUDINAL; LT, LONG TRANSVERSE; ST, SHORT TRANSVERSE

Table III

TABLE III

MECHANICAL PROPERTIES OF STRESS-RELIEVED 2024-T852 ALUMINUM ALLOY HAND FORGINGS
(F33615-68-C-1385)

| SAMPLE | | | TENSILE | | | | COMP. | SHEAR | BEARING ‡ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | EDGEWISE | | | |
| | | | | | | | | | ULT. STRESS, PSI | | YIELD STRESS, † PSI | |
| CROSS-SECTIONAL SIZE, IN. | NUMBER | DIRECTION § | ULT. STRESS, PSI | YIELD STRESS, * PSI | ELONG. IN 2 IN. OR 4D, % | RED. OF AREA, % | YIELD STRESS, * PSI | ULT. STRESS, PSI | e/D=1.5 | e/D=2.0 | e/D=1.5 | e/D=2.0 |
| 2X 8 | 341017 | L | 70 800 | 64 600 | 7.0 | 28 | 70 200 | 42 700 | 97 700 | 133 100 | 95 500 | 116 300 |
| | | LT | 72 300 | 63 800 | 9.0 | 17 | 72 700 | 41 800 | 94 500 | 125 900 | 89 500 | 114 200 |
| | | ST | 67 400 | 64 000 | 1.6 | 3 | 74 600 | --- | --- | --- | --- | --- |
| 3X12 | 341018 | L | 72 200 | 66 700 | 5.5 | 18 | 70 000 | 42 400 | 94 900 | 123 400 | 93 700 | 109 300 |
| | | LT | 73 700 | 69 000 | 3.0 | 2 | 75 800 | 42 000 | 94 500 | 126 100 | 93 500 | 113 300 |
| | | ST | 68 100 | 64 400 | 1.0 | 2 | 72 200 | 40 200 | --- | --- | --- | --- |
| 4X 8 | 341019 | L | 68 900 | 61 100 | 9.0 | 26 | 62 200 | 40 500 | 91 900 | 117 900 | 82 500 | 106 500 |
| | | LT | 70 400 | 63 200 | 5.0 | 8 | 63 500 | 39 500 | 88 800 | 119 400 | 82 800 | 101 000 |
| | | ST | 65 700 | 57 200 | 3.2 | 4 | 65 500 | 38 600 | --- | --- | --- | --- |
| 4X16 | 341020 | L | 71 400 | 65 400 | 6.5 | 23 | 66 600 | 41 100 | 92 100 | 124 000 | 87 400 | 104 800 |
| | | LT | 71 000 | 65 200 | 5.0 | 8 | 71 500 | 40 200 | 91 500 | 127 100 | 90 500 | 108 200 |
| | | ST | 70 100 | 60 600 | 2.4 | 6 | 70 200 | 39 900 | --- | --- | --- | --- |
| 5X 5 | 341021 | L | 69 000 | 62 000 | 8.5 | 29 | 63 400 | 40 800 | 93 500 | 125 200 | 89 900 | 105 100 |
| | | LT | 68 400 | 62 100 | 3.0 | 1 | 63 100 | 40 700 | 89 100 | 121 600 | 84 400 | 101 100 |
| | | ST | 66 500 | 56 000 | 2.8 | 4 | 64 700 | 39 600 | --- | --- | --- | --- |
| 5X10 | 341022 | L | 68 400 | 61 000 | 8.5 | 25 | 63 000 | 40 300 | 89 100 | 114 300 | 87 700 | 96 800 |
| | | LT | 69 100 | 61 500 | 6.0 | 8 | 64 800 | 39 700 | 89 500 | 120 200 | 85 100 | 99 600 |
| | | ST | 66 100 | 59 800 | 1.5 | 4 | 68 400 | 38 800 | --- | --- | --- | --- |
| 5X20 | 341023 | L | 65 200 | 55 100 | 9.0 | 16 | 57 800 | 38 800 | 83 600 | 112 600 | 79 300 | 94 400 |
| | | LT | 62 800 | 56 700 | 3.0 | 4 | 60 700 | 38 000 | 84 900 | 114 600 | 82 500 | 98 000 |
| | | ST | 63 200 | 54 500 | 3.0 | 3 | 59 400 | 37 000 | --- | --- | --- | --- |
| 6X 6 | 341024 | L | 69 100 | 61 600 | 9.0 | 28 | 63 700 | 41 500 | 95 300 | 123 900 | 89 800 | 102 200 |
| | | LT | 68 800 | 60 600 | 6.5 | 10 | 61 500 | 40 600 | 92 000 | 123 200 | 86 900 | 102 700 |
| | | ST | 69 400 | 58 500 | 2.3 | 3 | 67 600 | 39 800 | --- | --- | --- | --- |
| 6X12 | 341025 | L | 67 000 | 58 700 | 8.0 | 22 | 59 700 | 39 600 | 84 700 | 117 100 | 82 400 | 100 500 |
| | | LT | 67 400 | 60 200 | 3.2 | 4 | 63 500 | 38 400 | 85 700 | 113 400 | 81 400 | 95 700 |
| | | ST | 65 300 | 55 100 | 2.9 | 3 | 63 000 | 37 400 | --- | --- | --- | --- |
| 6X24 | 341026 | L | 64 300 | 56 100 | 7.5 | 20 | 56 000 | 37 100 | | 111 700 | | 95 000 |
| | | LT | 65 400 | 57 800 | 5.0 | 8 | 57 500 | 36 100 | | 98 600 | | 90 600 |
| | | ST | 58 200 | 53 600 | 1.5 | 2 | 58 000 | 34 900 | --- | --- | --- | --- |

* OFFSET EQUALS 0.2 PER CENT
† OFFSET EQUALS 2 PER CENT OF PIN DIAMETER
‡ SPECIMENS AND FIXTURES CLEANED ULTRASONICALLY
§ L, LONGITUDINAL ; LT, LONG TRANSVERSE ; ST, SHORT TRANSVERSE

TABLE IV

MECHANICAL PROPERTIES OF STRESS-RELIEVED 7075-T7352 ALUMINUM ALLOY HAND FORGINGS
(F33615-68-C-1385)

| SAMPLE | | | TENSILE | | | | COMP. | SHEAR | BEARING‡ EDGEWISE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | ULT. STRESS, PSI | | YIELD STRESS,† PSI | |
| CROSS-SECTIONAL SIZE, IN. | NUMBER | DIRECTION§ | ULT. STRESS,* PSI | YIELD STRESS, PSI | ELONG. IN 2 IN. OR 4D, % | RED. OF AREA, % | YIELD STRESS,* PSI | ULT. STRESS, PSI | e/D=1.5 | e/D=2.0 | e/D=1.5 | e/D=2.0 |
| 2X 8 | 341027 | L | 73 700 | 65 300 | 13.5 | 43 | 69 300 | 46 800 | 111 900 | 147 200 | 93 700 | 111 200 |
| | | LT | 74 900 | 65 300 | 13.5 | 29 | 68 800 | 44 500 | 110 600 | 146 300 | 92 700 | 106 500 |
| | | ST | 73 100 | 61 800 | 6.3 | 9 | 69 300 | --- | --- | --- | --- | --- |
| 3X12 | 341028 | L | 76 400 | 66 200 | 11.5 | 27 | 66 900 | 42 400 | 103 100 | 136 100 | 89 000 | 103 800 |
| | | LT | 71 400 | 59 300 | 8.0 | 11 | 65 300 | 42 600 | 98 300 | 135 100 | 89 800 | 110 300 |
| | | ST | 73 000 | 60 800 | 4.2 | 5 | 69 300 | 42 900 | --- | --- | --- | --- |
| 4X 8 | 341029 | L | 68 400 | 57 300 | 15.0 | 42 | 60 200 | 39 800 | 95 100 | 130 000 | 83 500 | 98 600 |
| | | LT | 65 100 | 53 000 | 10.0 | 17 | 57 600 | 38 400 | 98 500 | 127 100 | 81 400 | 99 000 |
| | | ST | 64 500 | 50 600 | 6.4 | 10 | 57 500 | 38 200 | --- | --- | --- | --- |
| 4X16 | 341030 | L | 70 000 | 59 500 | 13.0 | 34 | 57 400 | 40 600 | 95 300 | 126 000 | 82 900 | 95 800 |
| | | LT | 67 600 | 55 200 | 12.0 | 25 | 59 700 | 40 700 | 94 200 | 125 500 | 82 600 | 99 200 |
| | | ST | 64 800 | 52 500 | 6.4 | 7 | 58 600 | 39 100 | --- | --- | --- | --- |
| 5X 5 | 341031 | L | 68 400 | 56 700 | 14.0 | 39 | 59 400 | 41 500 | 104 400 | 131 600 | 84 300 | 99 000 |
| | | LT | 67 200 | 55 100 | 10.5 | 20 | 56 600 | 40 600 | 98 000 | 131 800 | 83 500 | 100 700 |
| | | ST | 63 800 | 51 700 | 4.0 | 6 | 59 500 | 41 500 | --- | --- | --- | --- |
| 5X10 | 341032 | L | 65 200 | 52 700 | 14.0 | 37 | 53 400 | 39 600 | 95 900 | 124 600 | 82 300 | 91 900 |
| | | LT | 64 000 | 51 400 | 9.0 | 17 | 53 800 | 38 500 | 97 700 | 127 100 | 80 100 | 97 000 |
| | | ST | 64 200 | 49 500 | 7.0 | 9 | 58 000 | 39 400 | --- | --- | --- | --- |
| 5X20 | 341033 | L | 64 800 | 52 500 | 14.5 | 35 | 52 200 | 38 800 | 94 100 | 120 300 | 76 800 | 89 100 |
| | | LT | 64 000 | 50 700 | 11.0 | 25 | 54 400 | 38 300 | 91 500 | 119 400 | 77 100 | 92 600 |
| | | ST | 63 700 | 49 300 | 6.5 | 10 | 54 900 | 38 000 | --- | --- | --- | --- |
| 6X 6 | 341034 | L | 62 400 | 51 100 | 15.0 | 44 | 54 000 | 41 300 | 99 300 | 131 200 | 82 100 | 94 400 |
| | | LT | 63 800 | 52 100 | 10.0 | 23 | 53 000 | 40 100 | 97 400 | 128 400 | 81 600 | 96 100 |
| | | ST | 63 400 | 49 700 | 8.0 | 14 | 55 300 | 39 000 | --- | --- | --- | --- |
| 6X12 | 341035 | L | 63 300 | 52 600 | 12.5 | 34 | | | | | | |
| | | LT | 63 400 | 50 900 | 9.0 | 14 | | | | | | |
| | | ST | 60 800 | 49 800 | 6.5 | 9 | | | --- | --- | --- | --- |
| 6X24 | 341036 | L | | | | | | | | | | |
| | | LT | | | | | | | | | | |
| | | ST | | | | | | | --- | --- | --- | --- |

* OFFSET EQUALS 0.2 PER CENT
† OFFSET EQUALS 2 PER CENT OF PIN DIAMETER
‡ SPECIMENS AND FIXTURES CLEANED ULTRASONICALLY
§ L, LONGITUDINAL; LT, LONG TRANSVERSE; ST, SHORT TRANSVERSE

TABLE V

MECHANICAL PROPERTIES OF STRESS-RELIEVED 7079-T652 ALUMINUM ALLOY HAND FORGINGS
(F33615-68-C-1385)

| SAMPLE | | | TENSILE | | | | COMP. | SHEAR | BEARING‡ EDGEWISE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | ULT. STRESS, PSI | | YIELD STRESS,† PSI | |
| CROSS-SECTIONAL SIZE, IN. | NUMBER | DIRECTION§ | ULT. STRESS, PSI | YIELD STRESS,* PSI | ELONG. IN 2 IN. OR 4D, % | RED. OF AREA, % | YIELD STRESS,* PSI | ULT. STRESS, PSI | e/D=1.5 | e/D=2.0 | e/D=1.5 | e/D=2.0 |
| 2X 8 | 341037 | L | 78 600 | 71 000 | 14.0 | 34 | 73 300 | 48 700 | 115 100 | 154 700 | 99 100 | 114 400 |
| | | LT | 76 100 | 64 900 | 12.0 | 20 | 73 200 | 46 500 | 114 500 | 149 100 | 98 000 | 113 400 |
| | | ST | 76 000 | 63 700 | 7.8 | 10 | 74 200 | --- | --- | --- | --- | --- |
| 3X12 | 341038 | L | 77 500 | 68 700 | 13.0 | 26 | 71 300 | 46 400 | 113 200 | 148 800 | 94 800 | 112 900 |
| | | LT | 76 100 | 65 700 | 12.0 | 26 | 70 700 | 46 100 | 116 600 | 149 100 | 97 900 | 114 600 |
| | | ST | 73 700 | 61 400 | 8.0 | 11 | 71 800 | 45 400 | --- | --- | --- | --- |
| 4X 8 | 341039 | L | 78 800 | 69 600 | 11.0 | 21 | 72 800 | 48 900 | 111 500 | 148 300 | 99 400 | 115 200 |
| | | LT | 77 500 | 66 500 | 11.5 | 24 | 72 900 | 48 200 | 117 100 | 148 700 | 102 300 | 117 200 |
| | | ST | 74 300 | 62 800 | 5.0 | 6 | 73 200 | 47 300 | --- | --- | --- | --- |
| 4X16 | 341040 | L | 77 900 | 68 000 | 12.0 | 22 | 70 100 | 46 600 | 113 000 | 145 900 | 95 200 | 110 300 |
| | | LT | 74 600 | 63 000 | 9.5 | 18 | 66 800 | 45 700 | 107 500 | 144 400 | 94 000 | 105 700 |
| | | ST | 74 000 | 62 900 | 7.9 | 17 | 70 600 | 44 900 | --- | --- | --- | --- |
| 5X 5 | 341041 | L | 75 600 | 67 600 | 13.0 | 27 | 69 700 | 47 900 | 112 600 | 149 900 | 94 400 | 108 900 |
| | | LT | 72 900 | 63 000 | 8.5 | 12 | 67 000 | 45 900 | 105 200 | 143 600 | 92 100 | 107 800 |
| | | ST | 71 300 | 59 500 | 7.0 | 10 | 68 400 | 46 300 | --- | --- | --- | --- |
| 5X10 | 341042 | L | 76 100 | 68 000 | 13.0 | 27 | 68 800 | 45 700 | 108 200 | 140 900 | 92 800 | 107 000 |
| | | LT | 74 100 | 62 600 | 10.5 | 19 | 69 300 | 45 900 | 108 300 | 141 300 | 94 300 | 109 100 |
| | | ST | 73 000 | 61 300 | 5.5 | 5 | 72 200 | 44 400 | --- | --- | --- | --- |
| 5X20 | 341043 | L | 76 900 | 65 600 | 13.0 | 24 | 67 000 | 46 200 | 104 600 | 135 900 | 91 800 | 106 400 |
| | | LT | 73 300 | 61 400 | 11.0 | 19 | 65 700 | 46 400 | 103 300 | 136 900 | 89 800 | 105 400 |
| | | ST | 71 300 | 58 300 | 6.0 | 7 | 68 300 | 44 000 | --- | --- | --- | --- |
| 6X 6 | 341044 | L | 73 600 | 63 800 | 15.0 | 37 | 58 900 | 48 400 | 112 200 | 148 100 | 95 600 | 105 400 |
| | | LT | 72 600 | 61 400 | 9.0 | 16 | 69 700 | 47 900 | 111 000 | 146 000 | 96 700 | 109 400 |
| | | ST | 71 700 | 61 800 | 8.5 | 14 | 67 100 | 47 300 | --- | --- | --- | --- |
| 6X12 | 341045 | L | 75 200 | 65 700 | 11.0 | 25 | 67 500 | 46 300 | 109 000 | 139 300 | 93 800 | 107 500 |
| | | LT | 72 800 | 62 100 | 7.5 | 12 | 66 200 | 45 500 | 104 000 | 140 700 | 92 300 | 107 600 |
| | | ST | 72 400 | 58 800 | 6.0 | 7 | 69 300 | 44 700 | --- | --- | --- | --- |
| 6X24 | 341046 | L | 73 900 | 63 900 | 12.0 | 22 | 63 300 | 43 800 | 94 300 | 128 300 | 85 200 | 98 100 |
| | | LT | 69 100 | 57 500 | 10.0 | 22 | 62 900 | 42 000 | 87 700 | 123 300 | 83 300 | 97 200 |
| | | ST | 69 300 | 58 100 | 4.5 | 6 | 67 300 | 42 000 | --- | --- | --- | --- |

* OFFSET EQUALS 0.2 PER CENT
† OFFSET EQUALS 2 PER CENT OF PIN DIAMETER
‡ SPECIMENS AND FIXTURES CLEANED ULTRASONICALLY
§ L, LONGITUDINAL; LT, LONG TRANSVERSE; ST, SHORT TRANSVERSE

Table V

TABLE VI

RATIOS AMONG THE TENSILE, COMPRESSIVE, SHEAR AND BEARING PROPERTIES
OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS
(F33615-68-C-1395)

| ALLOY AND TEMPER | SAMPLE: CROSS SECT. SIZE, IN. | SAMPLE: NUMBER | CYS(L)/TYS(L) | CYS(LT)/TYS(LT) | CYS(ST)/TYS(ST) | SS(L)/TS(LT) | SS(LT)/TS(LT) | SS(ST)/TS(LT) | [illegible]: BS(L)/TS(LT) e/D= 1.5 | BS(L)/TS(LT) e/D= 2.0 | BYS(L)/TYS(LT) e/D= 1.5 | BYS(L)/TYS(LT) e/D= 2.0 | BS(LT)/TS(LT) e/D= 1.5 | BS(LT)/TS(LT) e/D= 2.0 | BYS(LT)/TYS(LT) e/D= 1.5 | BYS(LT)/TYS(LT) e/D= 2.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2014-T652 | 2X 8 | 341007 | 1.04 | 1.08 | 1.12 | 0.62 | 0.61 | --- | 1.41 | 1.71 | 1.35 | 1.56 | 1.41 | 1.81 | 1.38 | 1.54 |
| | 3X12 | 341008 | 1.03 | 1.07 | 1.12 | 0.59 | 0.59 | 0.58 | 1.44 | 1.87 | 1.38 | 1.65 | 1.37 | 1.78 | 1.36 | 1.56 |
| | 4X 8 | 341009 | 1.03 | 1.03 | 1.17 | 0.58 | 0.58 | 0.57 | 1.28 | 1.77 | 1.36 | 1.63 | 1.30 | 1.74 | 1.38 | 1.62 |
| | 4X16 | 341010 | 0.96 | 1.04 | 1.08 | 0.58 | 0.58 | 0.58 | 1.33 | 1.86 | 1.34 | 1.65 | | 1.73 | | 1.59 |
| | 5X 5 | 341011 | 1.03 | 1.02 | 1.13 | 0.62 | 0.60 | 0.61 | 1.31 | 1.74 | 1.40 | 1.65 | 1.29 | 1.75 | 1.40 | 1.66 |
| | 5X10 | 341012 | 1.02 | 1.02 | 1.14 | 0.60 | 0.60 | 0.57 | 1.39 | 1.74 | 1.37 | 1.57 | 1.32 | 1.83 | 1.39 | 1.64 |
| | 5X20 | 341013 | 1.01 | 1.11 | 1.12 | 0.60 | 0.59 | 0.59 | 1.39 | 1.75 | 1.38 | 1.65 | 1.34 | 1.82 | 1.38 | 1.65 |
| | 6X 6 | 341014 | 1.03 | 1.02 | 1.18 | 0.65 | 0.63 | 0.62 | 1.58 | 1.76 | 1.46 | 1.64 | 1.38 | 1.87 | 1.41 | 1.70 |
| | 6X12 | 341015 | 1.01 | 1.05 | 1.12 | 0.63 | 0.60 | 0.60 | 1.42 | 1.87 | 1.40 | 1.64 | 1.37 | 1.95 | 1.38 | 1.59 |
| | 6X24 | 341016 | 1.04 | 1.08 | 1.10 | 0.64 | 0.58 | 0.59 | 1.34 | 1.77 | 1.41 | 1.73 | 1.30 | 1.77 | 1.36 | 1.71 |
| 2024-T852 | 2X 8 | 341017 | 1.09 | 1.14 | 1.17 | 0.59 | 0.58 | --- | 1.35 | 1.84 | 1.50 | 1.92 | 1.31 | 1.74 | 1.40 | 1.79 |
| | 3X12 | 341018 | 1.05 | 1.10 | 1.12 | 0.58 | 0.57 | 0.55 | 1.29 | 1.67 | 1.36 | 1.58 | 1.28 | 1.71 | 1.36 | 1.64 |
| | 4X 8 | 341019 | 1.02 | 1.01 | 1.15 | 0.58 | 0.56 | 0.55 | 1.30 | 1.67 | 1.31 | 1.59 | 1.26 | 1.70 | 1.31 | 1.68 |
| | 4X16 | 341020 | 1.02 | 1.10 | 1.16 | 0.58 | 0.57 | 0.56 | 1.30 | 1.74 | 1.34 | 1.61 | 1.29 | 1.79 | 1.39 | 1.66 |
| | 5X 5 | 341021 | 1.02 | 1.02 | 1.15 | 0.60 | 0.59 | 0.58 | 1.37 | 1.83 | 1.45 | 1.69 | 1.30 | 1.78 | 1.36 | 1.63 |
| | 5X10 | 341022 | 1.03 | 1.05 | 1.14 | 0.58 | 0.57 | 0.56 | 1.29 | 1.65 | 1.43 | 1.57 | 1.29 | 1.74 | 1.38 | 1.62 |
| | 5X20 | 341023 | 1.05 | 1.07 | 1.09 | 0.62 | 0.61 | 0.59 | 1.33 | 1.79 | 1.40 | 1.67 | 1.35 | 1.83 | 1.46 | 1.73 |
| | 6X 6 | 341024 | 1.03 | 1.01 | 1.16 | 0.60 | 0.59 | 0.58 | 1.39 | 1.80 | 1.48 | 1.69 | 1.34 | 1.79 | 1.43 | 1.69 |
| | 6X12 | 341025 | 1.02 | 1.06 | 1.14 | 0.59 | 0.57 | 0.56 | 1.26 | 1.74 | 1.37 | 1.67 | 1.27 | 1.68 | 1.35 | 1.59 |
| | 6X24 | 341026 | 1.00 | 0.99 | 1.08 | 0.57 | 0.55 | 0.53 | | 1.71 | | 1.64 | | 1.51 | | 1.57 |
| 7075-T7352 | 2X [illegible] | 341027 | 1.06 | 1.05 | 1.12 | 0.62 | 0.59 | --- | 1.49 | 1.96 | 1.44 | 1.70 | 1.48 | 1.95 | 1.42 | 1.63 |
| | 3X12 | 341028 | 1.01 | 1.10 | 1.14 | 0.59 | 0.60 | 0.60 | 1.44 | 1.91 | 1.50 | 1.75 | 1.38 | 1.89 | 1.51 | 1.86 |
| | 4X 8 | 341029 | 1.05 | 1.09 | 1.14 | 0.61 | 0.59 | 0.59 | 1.46 | 2.00 | 1.58 | 1.86 | 1.51 | 1.95 | 1.54 | 1.87 |
| | 4X16 | 341030 | 0.96 | 1.08 | 1.12 | 0.60 | 0.60 | 0.58 | 1.41 | 1.86 | 1.50 | 1.73 | 1.39 | 1.86 | 1.50 | 1.80 |
| | 5X 5 | 341031 | 1.05 | 1.03 | 1.15 | 0.62 | 0.60 | 0.62 | 1.55 | 1.96 | 1.53 | 1.79 | 1.46 | 1.96 | 1.51 | 1.83 |
| | 5X10 | 341032 | 1.01 | 1.05 | 1.17 | 0.62 | 0.60 | 0.62 | 1.50 | 1.95 | 1.60 | 1.79 | 1.53 | 1.98 | 1.56 | 1.89 |
| | 5X20 | 341033 | 1.00 | 1.07 | 1.11 | 0.61 | 0.60 | 0.59 | 1.47 | 1.88 | 1.51 | 1.76 | 1.43 | 1.86 | 1.52 | 1.83 |
| | 6X 6 | 341034 | 1.05 | 1.02 | 1.11 | 0.65 | 0.63 | 0.61 | 1.56 | 2.06 | 1.58 | 1.81 | 1.53 | 2.01 | 1.57 | 1.84 |
| | 6X12 | 341035 | | | | | | | | | | | | | | |
| | 6X24 | 341036 | | | | | | | | | | | | | | |
| 7079-T652 | 2X 8 | 341037 | 1.03 | 1.13 | 1.17 | 0.64 | 0.61 | --- | 1.51 | 2.03 | 1.53 | 1.76 | 1.50 | 1.96 | 1.51 | 1.75 |
| | 3X12 | 341038 | 1.04 | 1.08 | 1.17 | 0.61 | 0.51 | 0.60 | 1.49 | 1.95 | 1.44 | 1.72 | 1.53 | 1.96 | 1.49 | 1.74 |
| | 4X 8 | 341039 | 1.05 | 1.10 | 1.16 | 0.63 | 0.62 | 0.61 | 1.44 | 1.91 | 1.50 | 1.73 | 1.51 | 1.92 | 1.54 | 1.76 |
| | 4X16 | 341040 | 1.03 | 1.06 | 1.12 | 0.62 | 0.61 | 0.60 | 1.52 | 1.96 | 1.51 | 1.75 | 1.44 | 1.94 | 1.49 | 1.68 |
| | 5X 5 | 341041 | 1.03 | 1.06 | 1.15 | 0.66 | 0.63 | 0.64 | 1.54 | 2.06 | 1.50 | 1.73 | 1.44 | 1.97 | 1.46 | 1.71 |
| | 5X10 | 341042 | 1.01 | 1.11 | 1.18 | 0.62 | 0.62 | 0.60 | 1.46 | 1.90 | 1.48 | 1.71 | 1.45 | 1.91 | 1.50 | 1.74 |
| | 5X20 | 341043 | 1.02 | 1.07 | 1.17 | 0.63 | 0.63 | 0.60 | 1.43 | 1.85 | 1.50 | 1.73 | 1.41 | 1.87 | 1.45 | 1.72 |
| | 6X 6 | 341044 | 1.08 | 1.14 | 1.09 | 0.67 | 0.66 | 0.65 | 1.55 | 2.04 | 1.56 | 1.72 | 1.53 | 2.01 | 1.58 | 1.78 |
| | 6X12 | 341045 | 1.03 | 1.07 | 1.18 | 0.64 | 0.63 | 0.61 | 1.50 | 1.91 | 1.51 | 1.73 | 1.43 | 1.93 | 1.49 | 1.73 |
| | 6X24 | 341046 | 0.99 | 1.09 | 1.16 | 0.63 | 0.61 | 0.61 | 1.36 | 1.86 | 1.48 | 1.71 | 1.27 | 1.78 | 1.45 | 1.69 |

Table VI

TABLE VII

SPECIFIED MINIMUM VALUES FOR ALUMINUM ALLOY HAND FORGINGS
(F33615-68-C-1385)

| Alloy and Temper | Thickness, in. | Longitudinal Tensile Strength, psi | Longitudinal Yield Strength,* psi | Longitudinal Elong. in 4D, % | Long-Transverse Tensile Strength, psi | Long-Transverse Yield Strength,* psi | Long-Transverse Elong. in 4D, % | Short-Transverse Tensile Strength, psi | Short-Transverse Yield Strength,* psi | Short-Transverse Elong. in 4D, % | Federal Specification |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2014-T652 | Up thru 2.000 | 65 000 | 56 000 | 8 | 65 000 | 56 000 | 3 | --- | --- | - | QQ-A-367g |
| | 2.001-3.000 | 64 000 | 55 000 | 8 | 64 000 | 55 000 | 3 | 62 000 | 52 000 | 2 | |
| | 3.001-4.000 | 63 000 | 55 000 | 8 | 63 000 | 55 000 | 3 | 61 000 | 51 000 | 2 | |
| | 4.001-5.000 | 62 000 | 54 000 | 7 | 62 000 | 54 000 | 2 | 60 000 | 50 000 | 1 | |
| | 5.001-6.000 | 61 000 | 53 000 | 7 | 61 000 | 53 000 | 2 | 59 000 | 50 000 | 1 | |
| 2024-T852 | All | --- | --- | - | --- | --- | - | --- | --- | - | None |
| 7075-T7352 | Up thru 3.000 | 66 000 | 54 000 | 7 | 64 000 | 52 000 | 4 | 61 000 | 50 000 | 3 | None** |
| | 3.001-4.000 | 64 000 | 53 000 | 7 | 63 000 | 50 000 | 3 | 60 000 | 48 000 | 2 | |
| | 4.001-5.000 | 62 000 | 51 000 | 7 | 61 000 | 48 000 | 3 | 58 000 | 46 000 | 2 | |
| | 5.001-6.000 | 61 000 | 49 000 | 6 | 59 000 | 46 000 | 3 | 57 000 | 44 000 | 2 | |
| 7079-T652 | Up thru 2.000 | 72 000 | 63 000 | 9 | 71 000 | 61 000 | 5 | --- | --- | - | QQ-A-367g |
| | 2.001-3.000 | 72 000 | 62 000 | 9 | 70 000 | 60 000 | 5 | 67 000 | 55 000 | 3 | |
| | 3.001-4.000 | 71 000 | 61 000 | 9 | 70 000 | 59 000 | 5 | 67 000 | 55 000 | 3 | |
| | 4.001-5.000 | 70 000 | 60 000 | 9 | 69 000 | 58 000 | 4 | 66 000 | 54 000 | 3 | |
| | 5.001-6.000 | 69 000 | 59 000 | 9 | 68 000 | 56 000 | 4 | 65 000 | 53 000 | 3 | |

* Offset equals 0.2 per cent.
** The Aluminum Association, "Aluminum Standards and Data", April 1968.

TABLE VII

# TABLE VIII

## RESULTS OF LONG-TRANSVERSE AXIAL-STRESS FATIGUE TESTS OF STRESS-RELIEVED ALUMINUM ALLOY HAND FORGINGS (R=0.0) (F33615-68-C-1385)

| Alloy and Temper | Sample Size, in. | Sample Number | Cycles to Failure | | |
|---|---|---|---|---|---|
| | Maximum Stress, psi | | 60 000 | 40 000 | 35 000 |
| 2014-T652 | 2x8 | 341007 | 34 200 | 4 358 100 | 10 264 500* |
| | 4x8 | 341009 | 17 700 | 1 032 800 | 6 252 200 |
| | 5x10 | 341012 | 18 900 | 230 000 | 10 017 300* |
| | 6x12 | 341015 | 7 700 | 142 200 | 14 323 200* |
| | Log-Mean Fatigue Life | | 17 200 | 619 400 | |
| 2024-T852 | 2x8 | 341017 | 22 600 | 252 900 | 10 029 500* |
| | 4x8 | 341019 | 12 700 | 180 700 | 19 845 700* |
| | 5x10 | 341022 | 14 300 | 90 200 | 17 189 300* |
| | 6x12 | 341015 | 7 200 | 93 600 | 14 882 400* |
| | Log-Mean Fatigue Life | | 13 700 | 140 200 | |
| | Maximum Stress, psi | | 60 000 | 45 000 | 38 000 |
| 7075-T7352 | 2x8 | 341027 | 28 100 | 4 084 800 | 14 882 600* |
| | 4x8 | 341029 | 4 700 | 82 400 | 1 455 800 |
| | 5x10 | 341032 | 9 800 | 51 100 | 105 800 |
| | 6x12 | 341035 | | | |
| | Log-Mean Fatigue Life | | | | |
| 7079-T652 | 2x8 | 341037 | 22 200 | 109 800 | 720 500 |
| | 4x8 | 341039 | 22 700 | 61 400 | 11 607 400* |
| | 5x10 | 341042 | 19 200 | 75 500 | 162 700 |
| | 6x12 | 341045 | 11 400 | 40 200 | 146 400 |
| | Log-Mean Fatigue Life | | 18 100 | 66 900 | |

* Specimen did not fail.

TABLE IX

STATUS OF LONGITUDINAL AND LONG-TRANSVERSE STRESS-CORROSION TESTS

TRIPLICATE 0.437" DIAMETER TENSION SPECIMENS STRESSED IN DIRECT TENSION*
EXPOSURE: 3.5% NaCl Solution by Alternate Immersion.
Dash Number and Days to Failure.†

| Alloy and Temper | Forging Size, in. | Sample Number | Longitudinal Specimens Stressed 75% Y.S. No. | Longitudinal Specimens Stressed 75% Y.S. Days | Long-Transverse Specimens Stressed 75% Y.S. No. | Long-Transverse Specimens Stressed 75% Y.S. Days | Long-Transverse Specimens Stressed 50% Y.S. No. | Long-Transverse Specimens Stressed 50% Y.S. Days |
|---|---|---|---|---|---|---|---|---|
| 2014-T652 | 2x8 | 341007 | L3 | | T3 | 64 | T6 | |
| | | | L4 | | T4 | 8 | T7 | |
| | | | L5 | | T5 | 59 | T8 | |
| 2024-T852 | 2x8 | 341017 | L3 | | T3 | | | |
| | | | L4 | | T4 | | | |
| | | | L5 | | T5 | | | |
| 7075-T7352 | 2x8 | 341027 | L3 | | T3 | | | |
| | | | L4 | | T4 | | | |
| | | | L5 | | T5 | | | |
| 7079-T652 | 2x8 | 341037 | L3 | | T3 | 59 | T6 | |
| | | | L4 | | T4 | 64 | T7 | |
| | | | L5 | | T5 | 27 | T8 | |

* Duplicate unstressed specimens were also exposed in each instance.

† Specimens were exposed November 24, 1968. When no entry is shown in the "Days" column, specimen has not failed.

TABLE X

STATUS OF SHORT-TRANSVERSE STRESS-CORROSION TESTS

TRIPLICATE 0.125" DIAMETER TENSION SPECIMENS STRESSED IN DIRECT TENSION *
EXPOSURE: 3.5% NaCl Solution by Alternate Immersion

| Alloy and Temper | Forging Size, in. | Sample Number | Stressed 75% Y.S. | | Stressed 50% Y.S. | | Stressed 22.5 ksi | | Stressed 15.0 ksi | | Stressed 7.5 ksi | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | F/N† | Days | F/N† | Days | F/N† | Days | F/N† | Days | F/N† | Days |
| 2014-T652 | 2x8 | 341007 | -- | -- | -- | -- | 0/3 | OK-78 | 0/3 | OK-78 | 0/3 | OK-78 |
| | 3x12 | 341008 | -- | -- | -- | -- | 3/3 | 6,8,8 | 0/3 | OK-78 | 0/3 | OK-78 |
| | 5x20 | 341013 | -- | -- | -- | -- | 0/3 | OK-78 | 0/3 | OK-78 | 0/3 | OK-78 |
| 2024-T852 | 2x8 | 341017 | 1/3 | 14 (2-OK-78) | 0/3 | OK-78 | -- | -- | -- | -- | -- | -- |
| | 3x12 | 341018 | 0/3 | OK-78 | 0/3 | OK-78 | -- | -- | -- | -- | -- | -- |
| | 5x20 | 341023 | 0/3 | OK-78 | 0/3 | OK-78 | -- | -- | -- | -- | -- | -- |
| 7075-T7352 | 2x8 | 341027 | 0/3 | OK-78 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 3x12 | 341028 | 3/3 | 8,8,8 | -- | -- | -- | -- | -- | -- | -- | -- |
| | 5x20 | 341033 | 0/3 | OK-78 | -- | -- | -- | -- | -- | -- | -- | -- |
| 7079-T652 | 2x8 | 341037 | -- | -- | -- | -- | 0/3 | OK-78 | 0/3 | OK-78 | 0/3 | OK-78 |
| | 3x12 | 341038 | -- | -- | -- | -- | 0/3 | OK-78 | 0/3 | OK-78 | 0/3 | OK-78 |
| | 5x20 | 341043 | -- | -- | -- | -- | 2/3 | 15,27(1-OK-78) | 0/3 | OK-78 | 0/3 | OK-78 |

* Duplicate unstressed specimens were also exposed in each instance.

† F/N denotes number of specimens failed over number exposed.

Table X

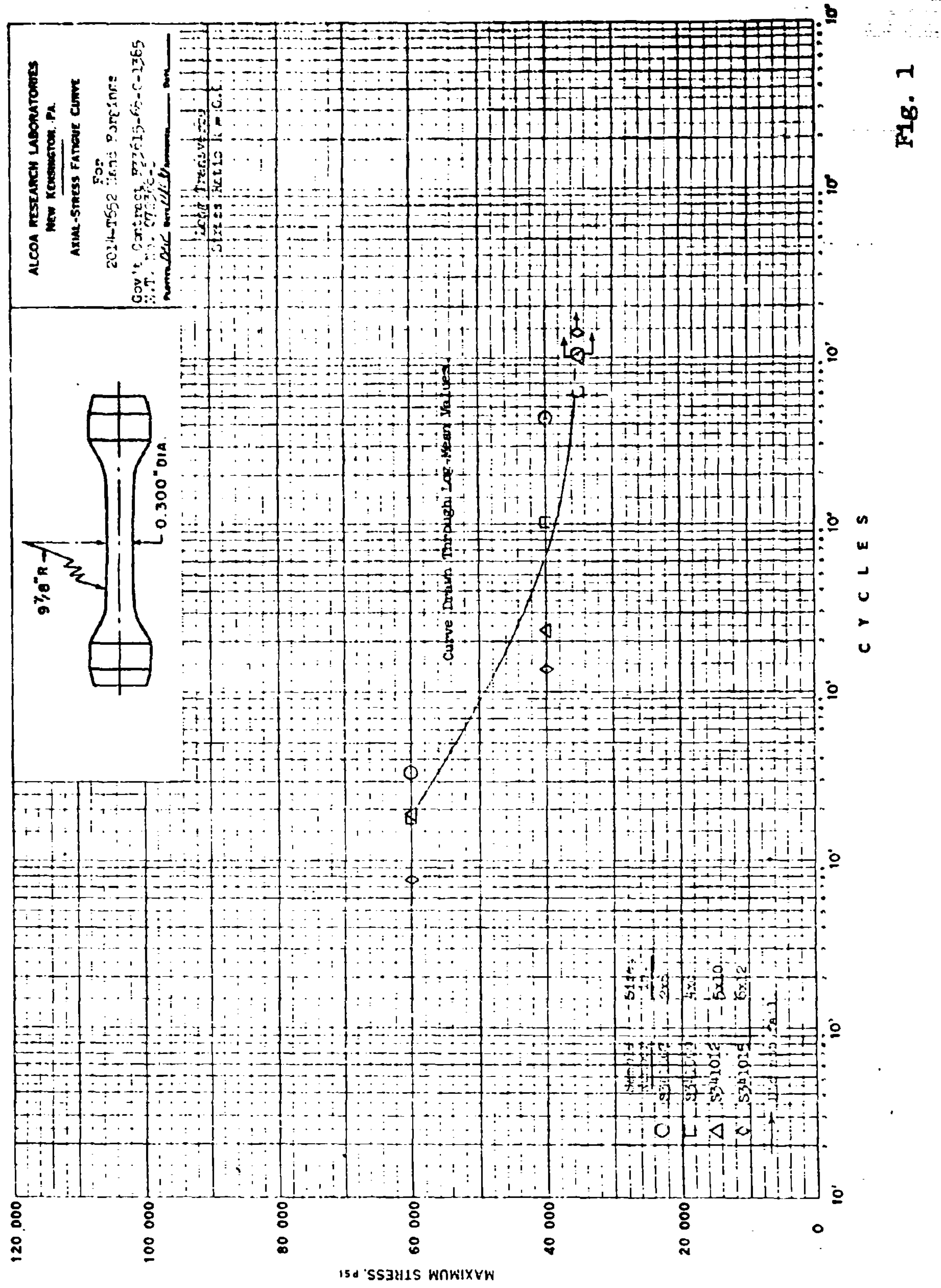

ALCOA RESEARCH LABORATORIES
New Kensington, Pa.
Axial-Stress Fatigue Curve
For
2014-T652 Hand Forgings
Stress Ratio R = 0.1
9 7/8" R
0.300" DIA.
Curve Drawn Through Log-Mean Values
120 000
100 000
80 000
60 000
40 000
20 000
0
MAXIMUM STRESS, PSI
C Y C L E S
Fig. 1

Fig. 1

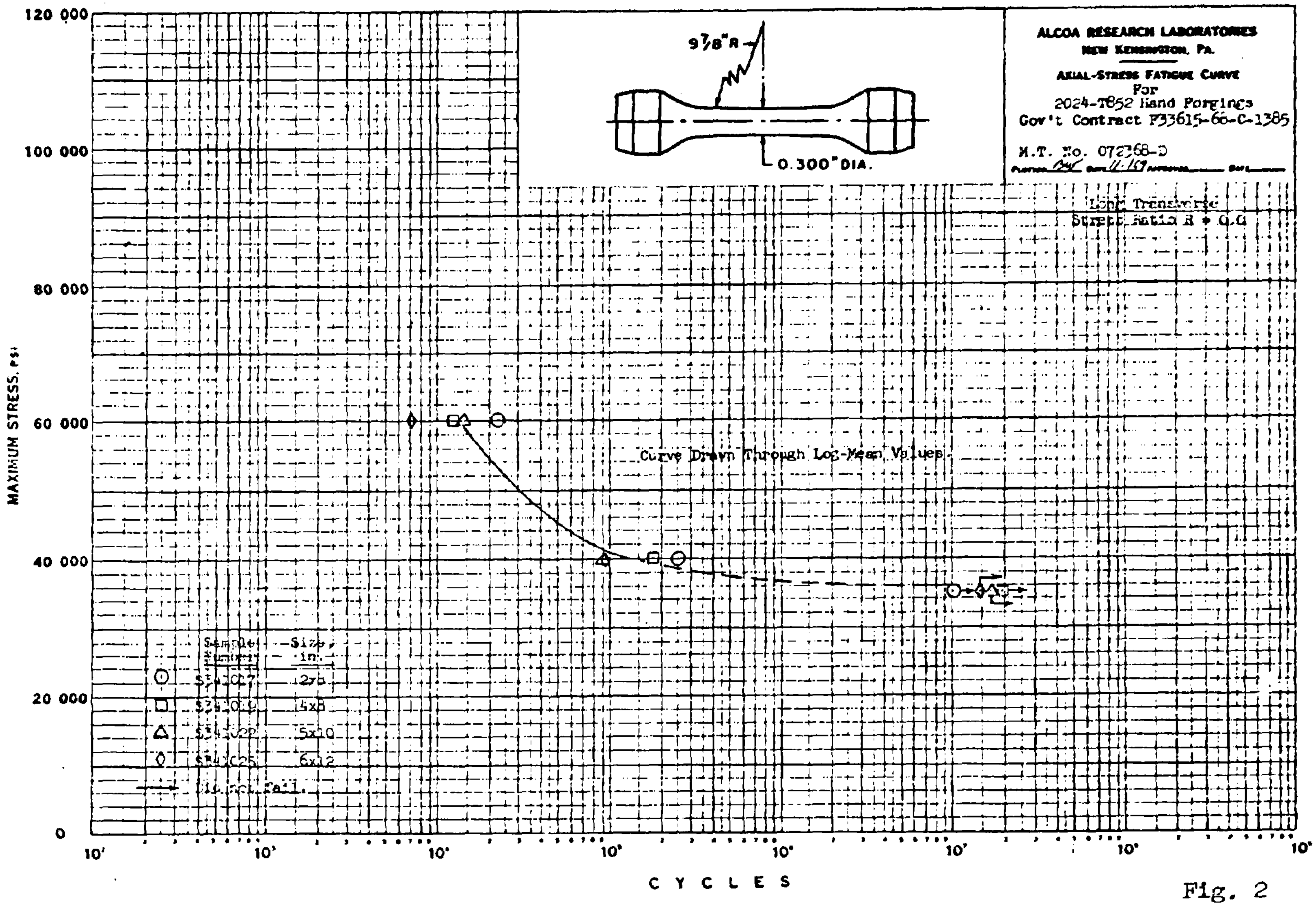

ALCOA RESEARCH LABORATORIES
NEW KENSINGTON, PA.
AXIAL-STRESS FATIGUE CURVE
For
2024-T852 Hand Forgings
Gov't Contract F33615-66-C-1385
M.T. No. 072368-D
9 7/8" R
0.300" DIA.
Long Transverse
Stress Ratio R = 0.0
Curve Drawn Through Log-Mean Values
Sample Number
Size, in.
4x8
5x10
6x12
120 000
100 000
80 000
60 000
40 000
20 000
0
MAXIMUM STRESS, PSI
CYCLES

Fig. 2

Fig. 2

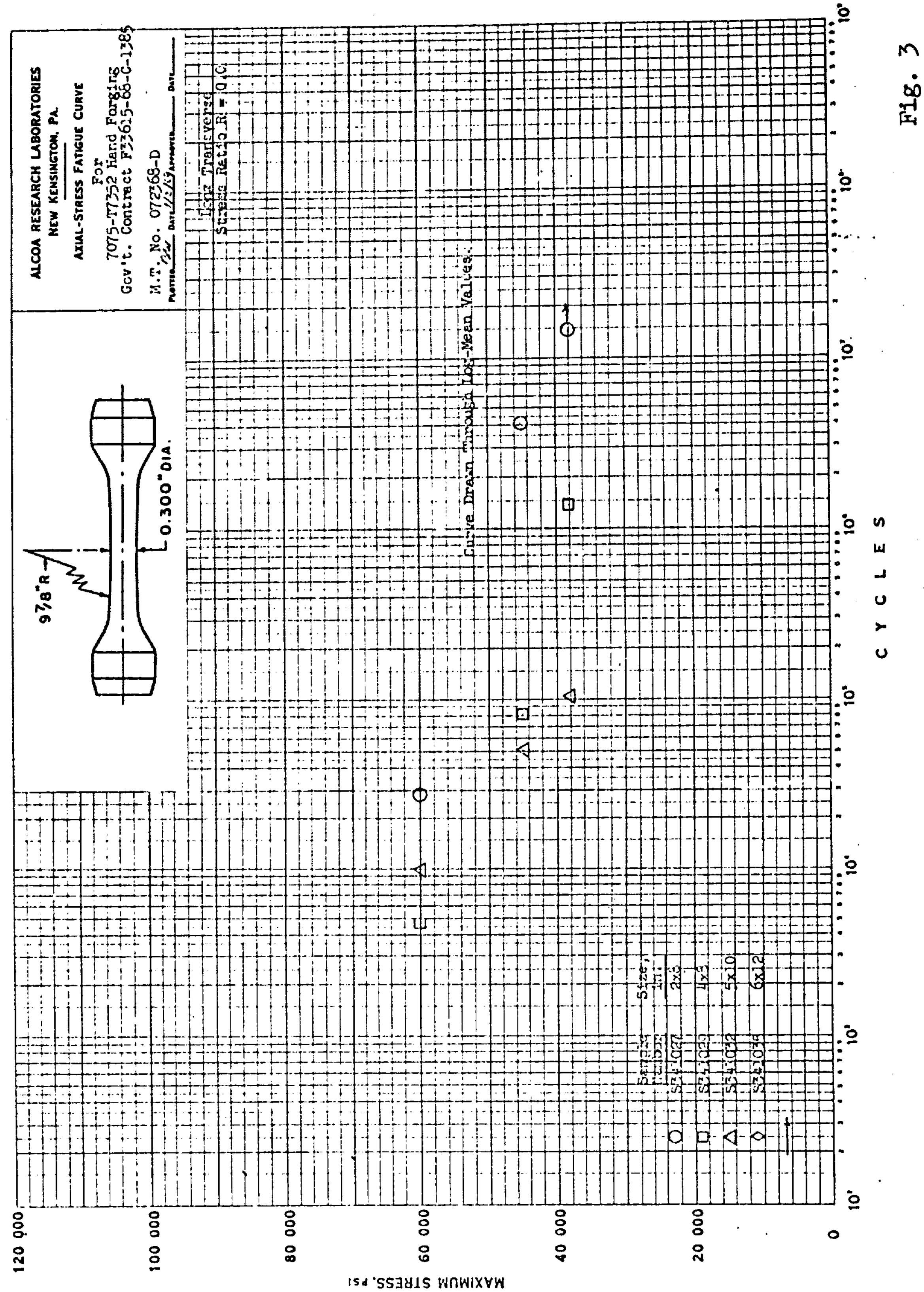

ALCOA RESEARCH LABORATORIES
NEW KENSINGTON, PA.
AXIAL-STRESS FATIGUE CURVE
For
7075-T7352 Hand Forging
Gov't. Contract F33615-68-C-1385
M.T. No. 072368-D
Curve Drawn Through Log-Mean Values
0.300" DIA.
9 7/8" R
MAXIMUM STRESS, PSI
CYCLES
Fig. 3

Fig. 3

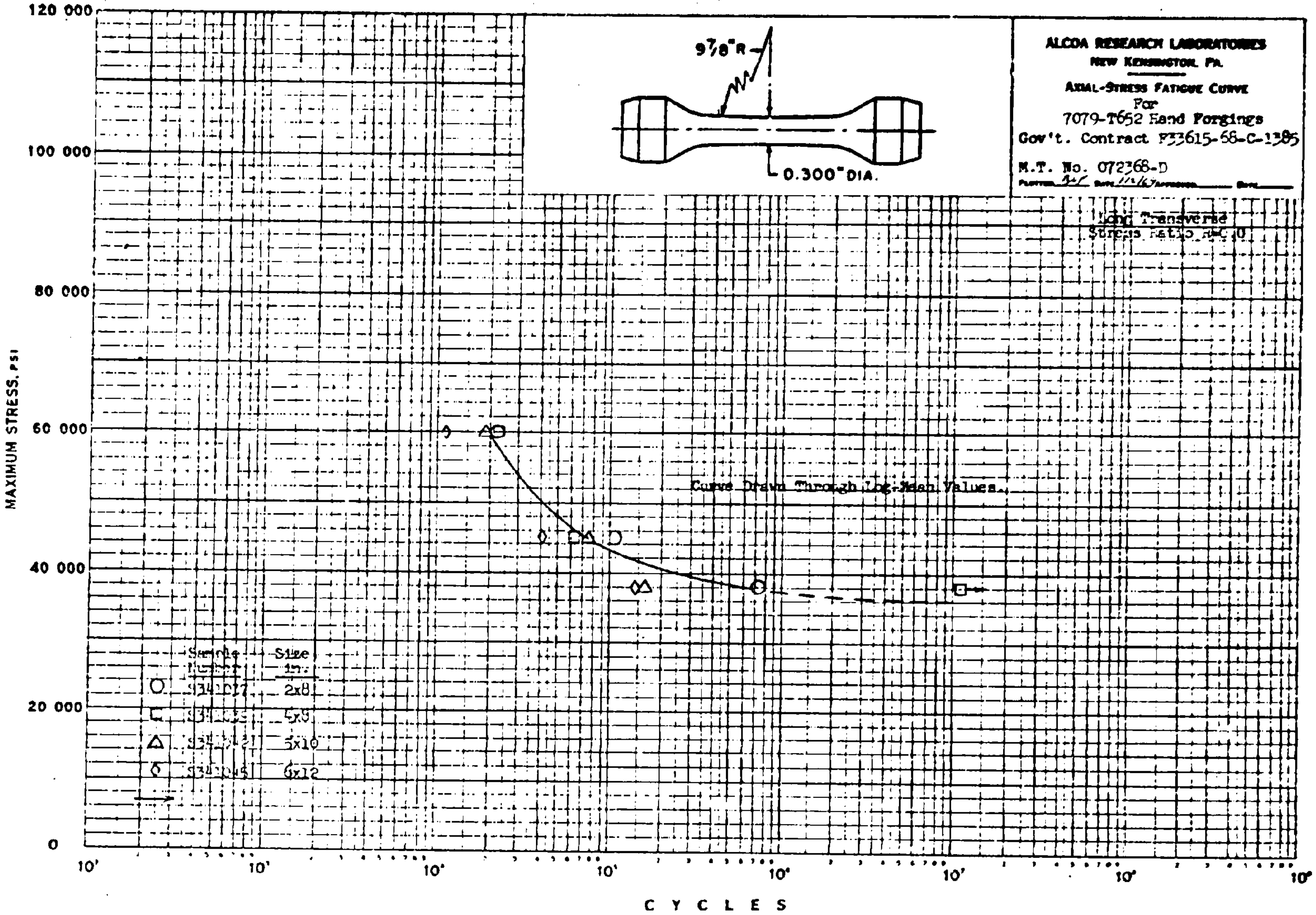

ALCOA RESEARCH LABORATORIES
NEW KENSINGTON, PA.
AXIAL-STRESS FATIGUE CURVE
For
7079-T652 Hand Forgings
Gov't. Contract F33615-68-C-1385
M.T. No. 072368-D
Long Transverse
9 7/8" R
0.300" DIA.
Curve Drawn Through Log-Mean Values.
Sample
Size
in.
2x8
4x9
5x10
6x12
MAXIMUM STRESS, PSI
120 000
100 000
80 000
60 000
40 000
20 000
0
CYCLES

Fig. 4

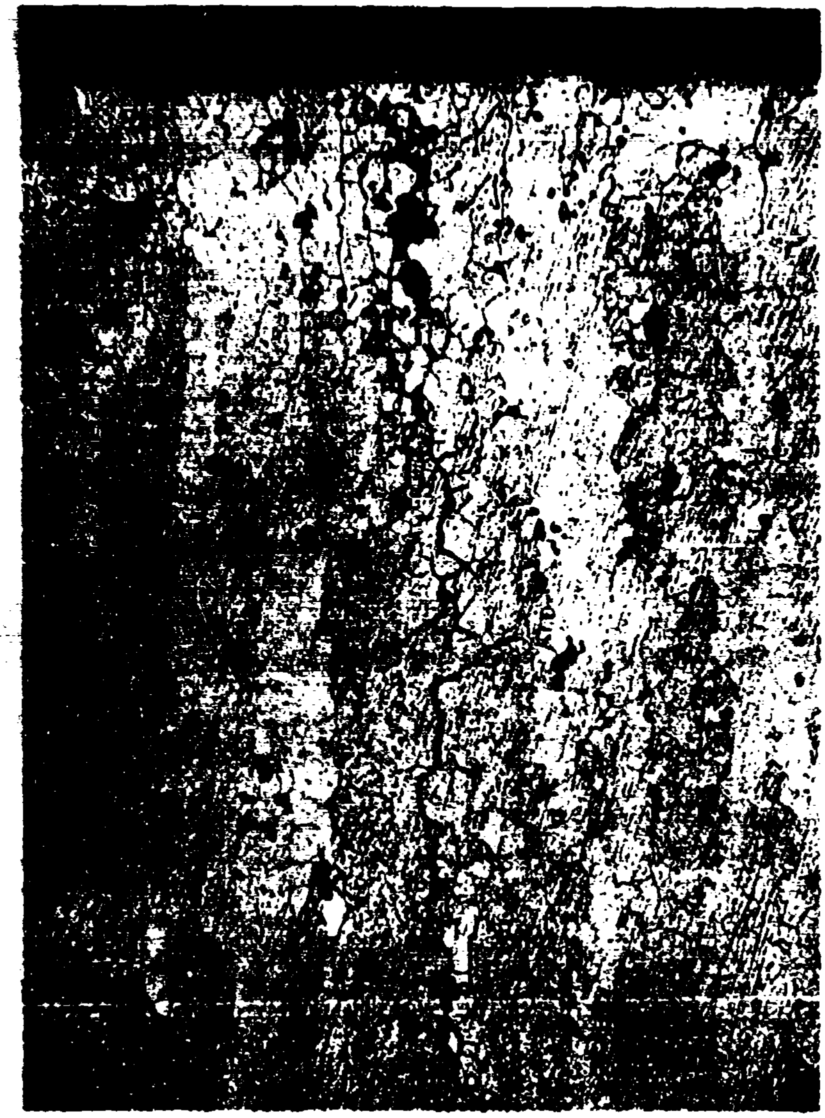
Fig. 4

S.No. 341007-T4 Etch: Keller's Mag. 100X

Fig. 5. Section Illustrating an Auxiliary Crack in Long-Transverse Specimen from 2-in. Thick 2014-T652 Forging which Failed at a Stress Equal to 75% Y.S.

S.No. 341007-T4 Etch: Keller's Mag. 500X

Fig. 6. Illustrates the Intergranular Character of the Crack Shown Above, Indicating that Failure was Result of Stress-Corrosion Cracking.

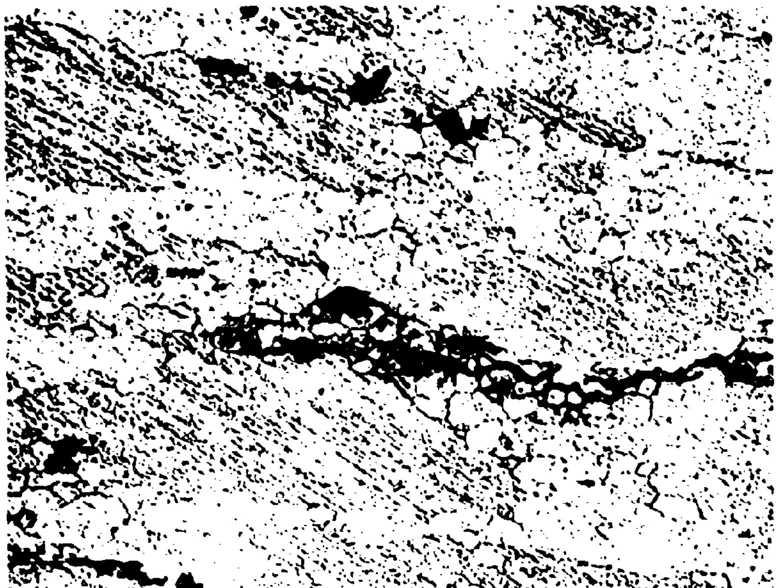


S.No. 341008-N11 Etch: Keller's Mag. 100X

Fig. 7. Section Through Specimen from 3-in. Thick 2014-T652 Forging which Failed at a Stress of 22.5 ksi (35% Y.S.). The Intergranular Character of This Auxiliary Crack is Indicative of Stress-Corrosion Cracking.

S.No. 341017-N4 Etch: Keller's Mag. 100X

Fig. 8. Section Illustrating Fine Auxiliary Crack in Specimen from 2-in. Thick 2024-T852 Forging Which Failed at a Stress Equal to 75% Y.S.



S. No. 341017-N4 Etch: Keller's Mag. 500X

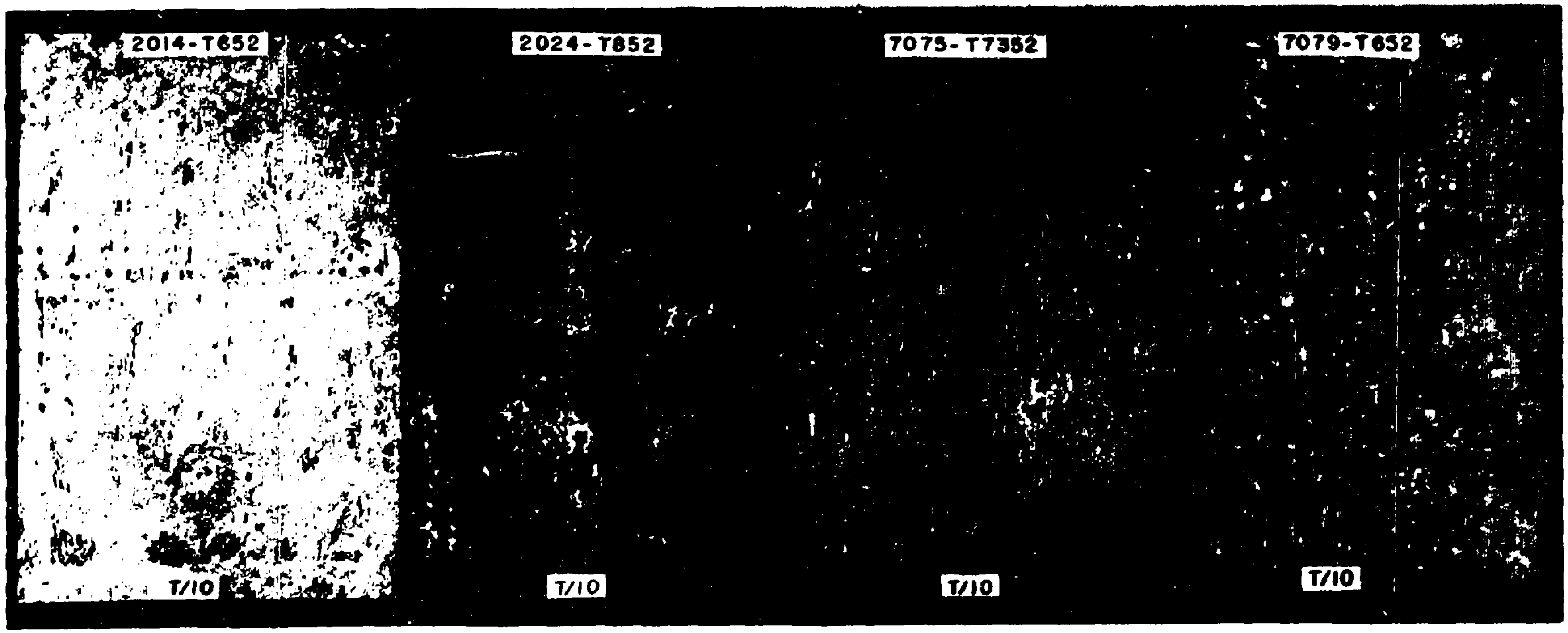
Fig. 9. Illustrates the Intergranular Character of the Crack Shown Above, Indicating that Failure Was the Result of Stress-Corrosion Cracking.

S. No. 341028-N3 Etch: Keller's Mag. 100X

Fig. 10. Section Illustrating Fine Auxiliary Crack in Specimen from 3-in. Thick 7075-T7352 Forging Which Failed at a Stress Equal to 75% Y.S.

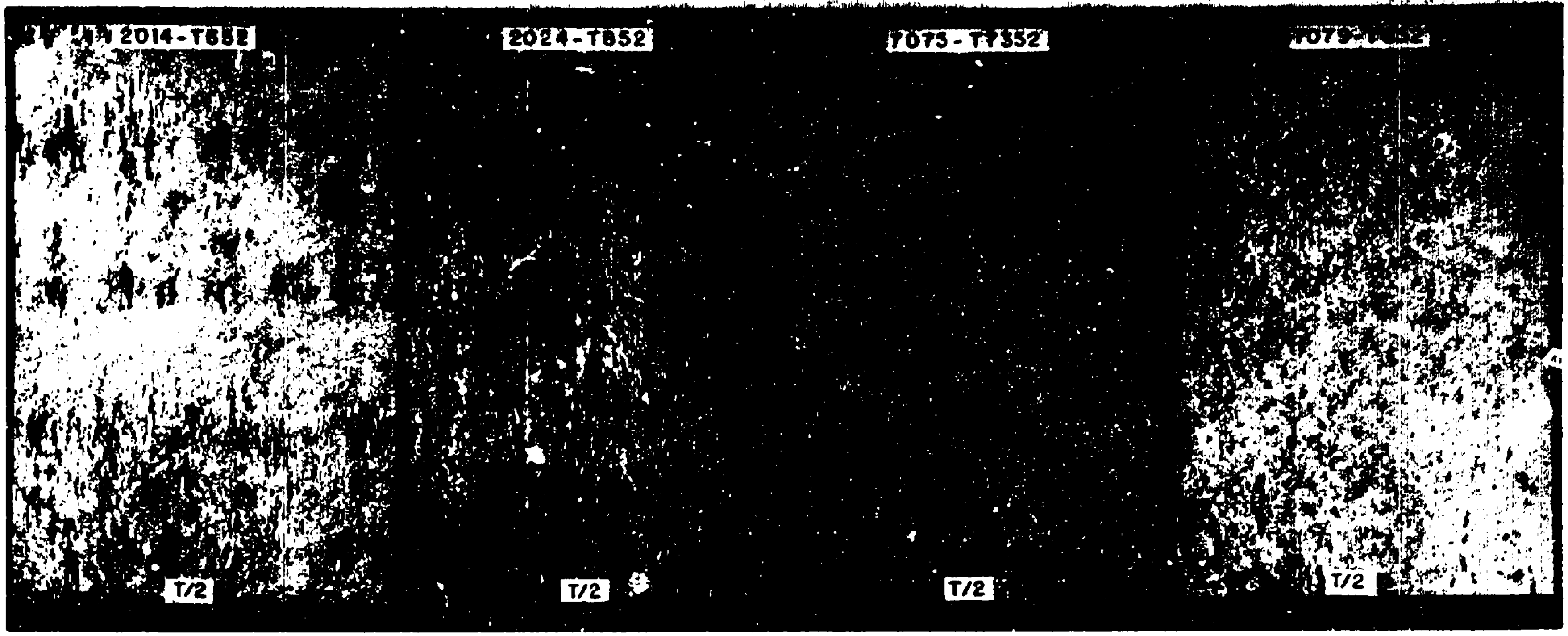
S. No. 341028-N3 Etch: Keller's Mag. 500X

Fig. 11. Illustrate the Intergranular Character of the Crack Shown Above, Indicating That Failure Was the Result of Stress-Corrosion Cracking.




Mag. 0.6X

Fig. 12. Illustrates Appearance of Specimens from the 2-in. Thick Forgings After Two Weeks Exposure to the Laboratory Rapid Exfoliation Test. Specimen Surface Corresponds to Plane 1/10 of Way Through the Forging Thickness.




Mag. 0.6X

Fig. 13. Illustrates Appearance of Specimens from the 2-in. Thick Forgings After Two Weeks Exposure to the Laboratory Rapid Exfoliation Test. Specimen Surface Corresponds to Plane at Center of Forging Thickness.

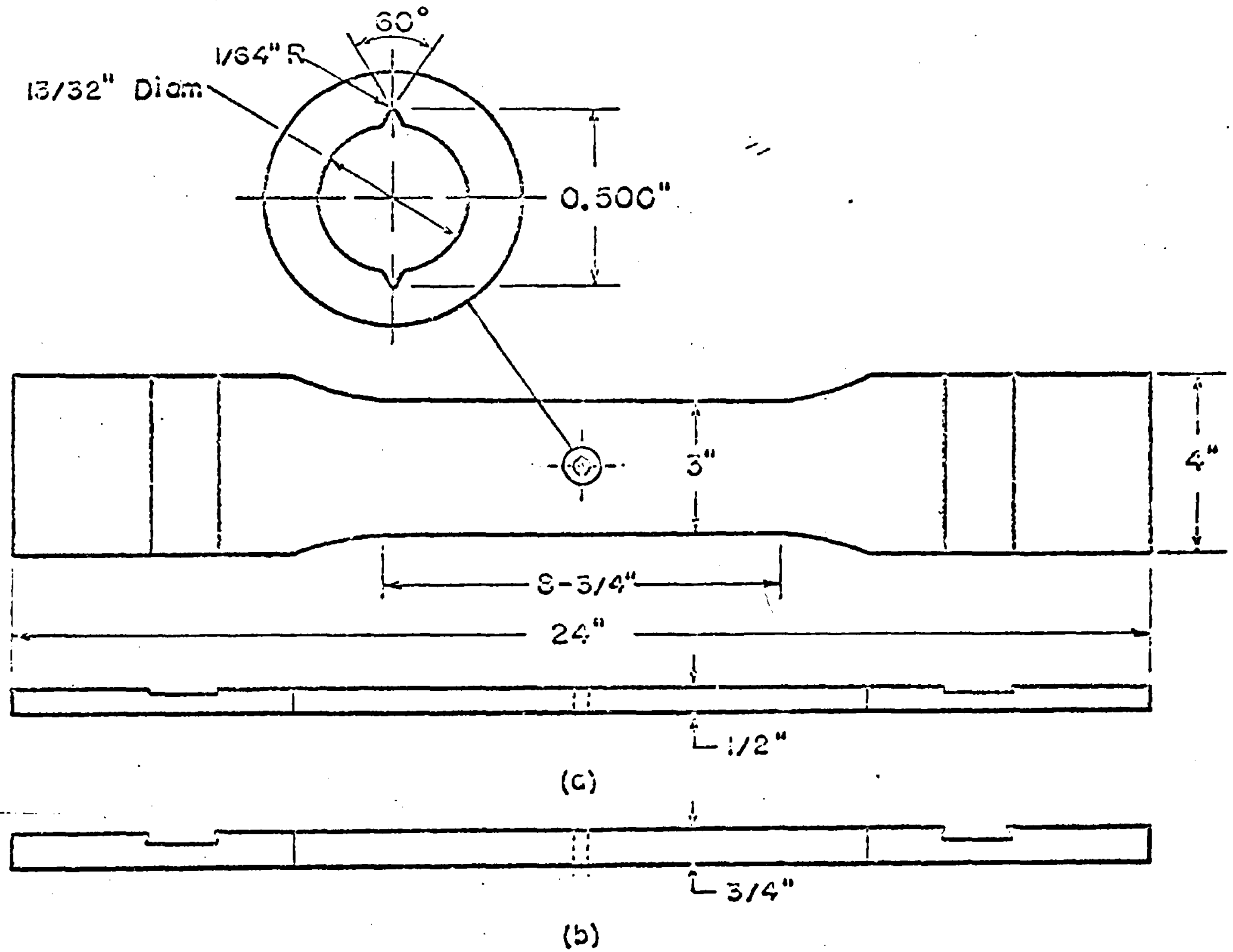



Fig. 14 Center-Notched Fatigue Specimen

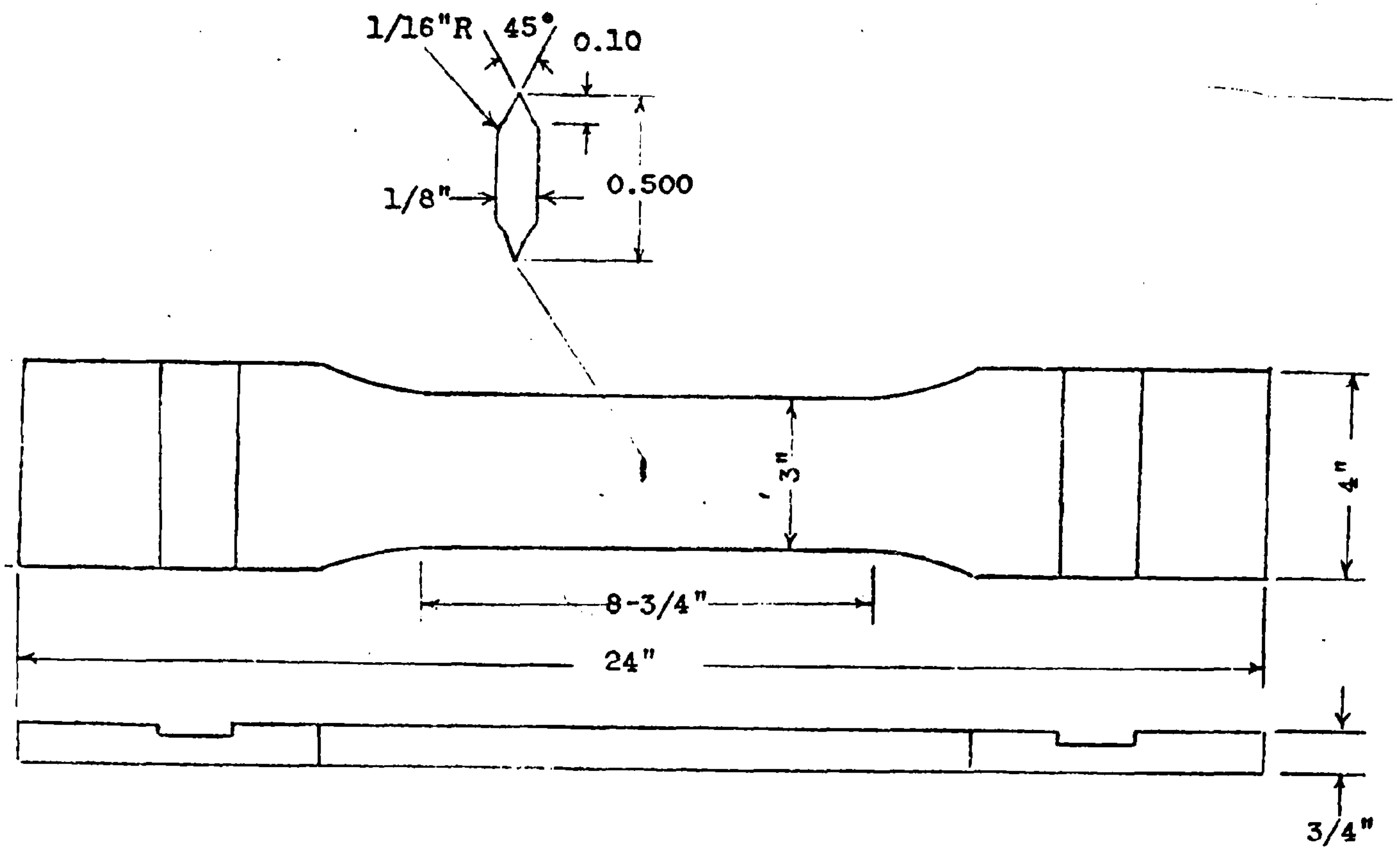
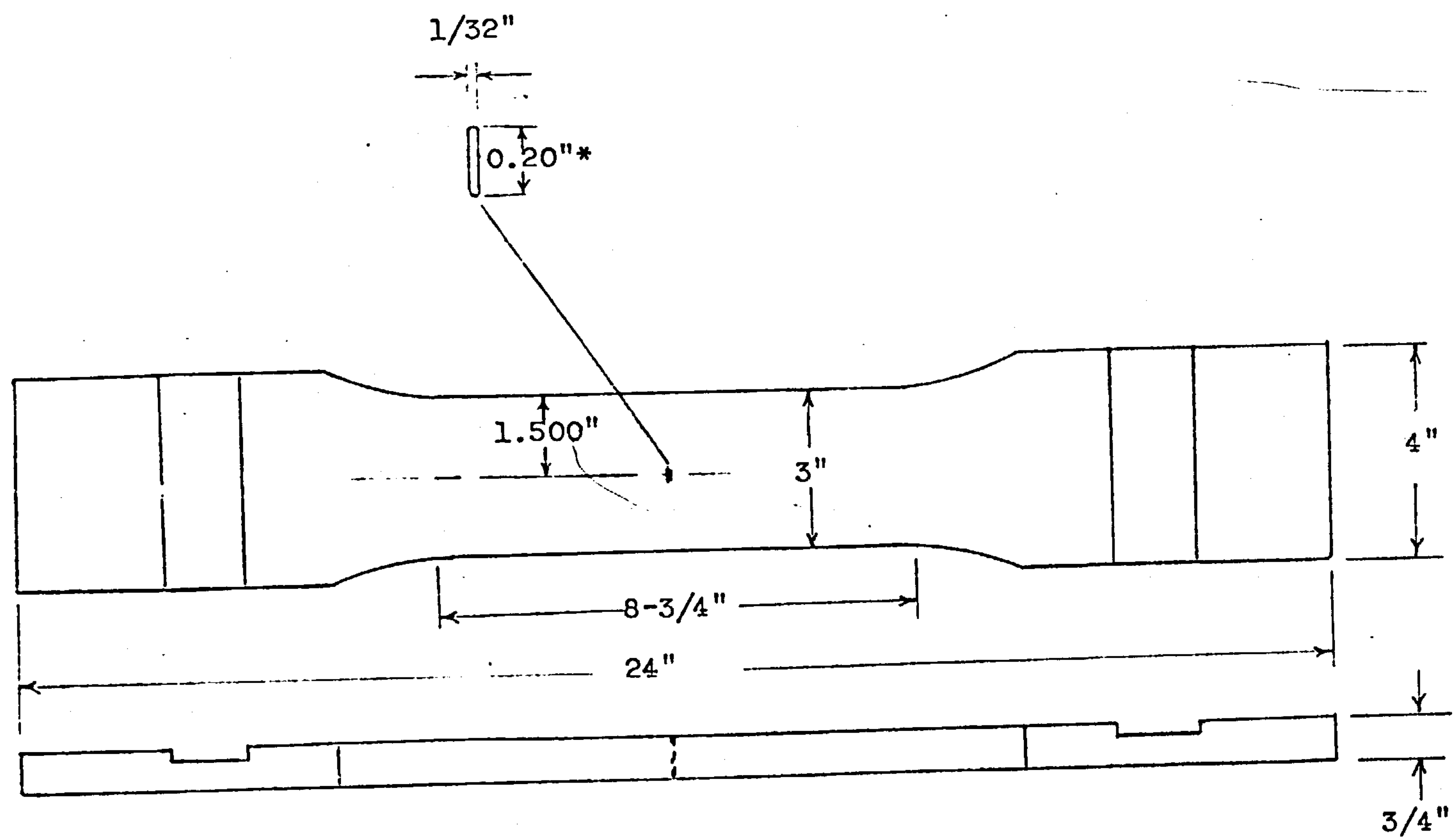
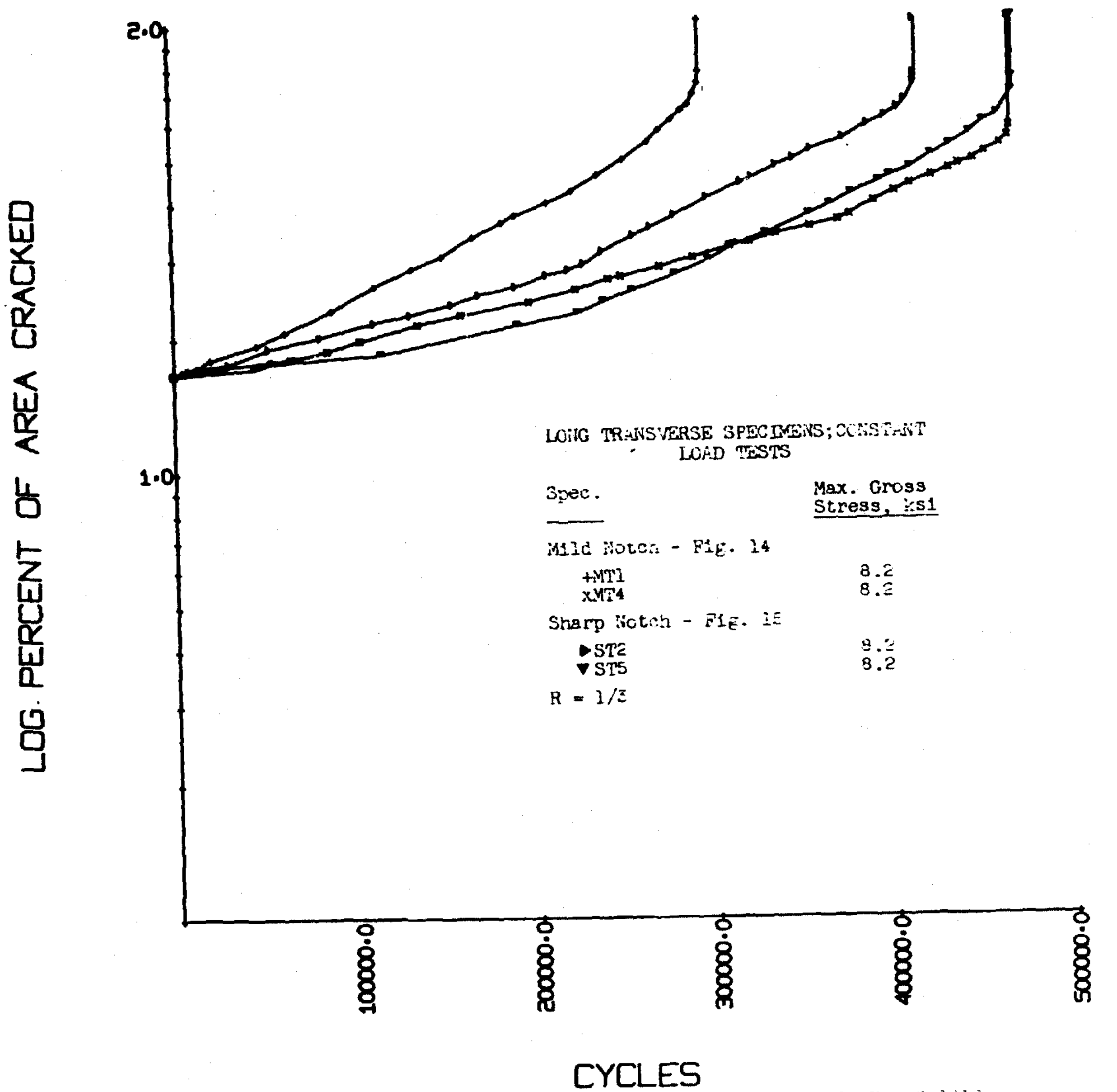



Fig. 15 Center-Notched Fatigue Specimen




*Specimen precracked to 0.50 in.

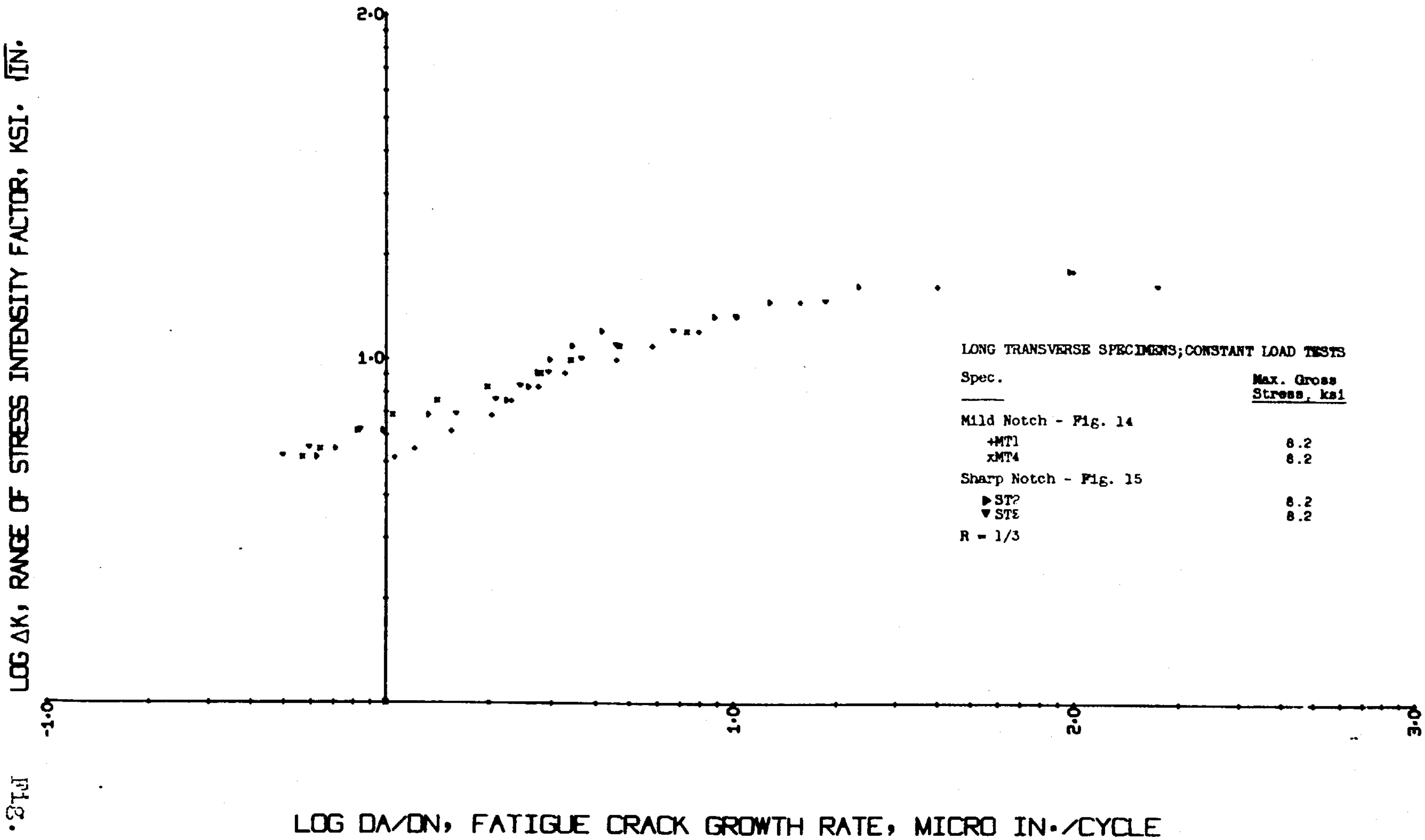
Fig. 16 Elox Notched Crack Propagation Specimen




FATIGUE CRACK PROPAGATION OF 2014-T652 FORGING - S. No. 342[illegible]

Fig. 17

Fig. 17




FATIGUE CRACK PROPAGATION RATES FOR 2014-T652 FORGING - S. No. 341016

Fig. 18

Fig. 18